# THE SALIENT FEATURES OF THE GEOLOGY OF OREGON.

WARREN DUPRE SMITH AND EARL L. PACKARD
University of Oregon, Eugene, Oregon



## INTRODUCTION

No article or book purporting to sum up the known geology of the whole of Oregon has yet been published. Even now the time has not arrived to essay anything like a complete story. Nevertheless it seems to be a propitious time to take an inventory of our knowledge. This seems desirable in that it will give those interested something like a connected account of the salient features, and on the other hand will afford the workers in the field a clearer idea of

the problems involved. The writers are personally acquainted with much of the field and have made up for some of the deficiencies in their own knowledge by drawing upon the literature which they have deemed most reliable. In some cases, as will be indicated in the proper places, they have taken issue with earlier workers.

A few scattered references to the geology of Oregon in the earliest reports of various kinds are mainly of historic interest, but naturally at that time could not throw much light on problems of Oregon geology.

Dr. Thomas Condon, formerly a missionary, who came to Oregon in 1852, and who because of an unquenchable love and aptitude for natural history became a geologist, was the pioneer geologist of this state. His popular book on *Oregon Geology* and his collections, the first to be made in the now famous John Day basin, and the general stimulus he gave to later workers are his contributions, and no one has left a finer legacy to present-day workers.

In his published contributions Dr. Josiah Diller, veteran geologist of the United States Geological Survey, takes the lead. His work began in 1883 and he has since covered most of western Oregon. After Diller comes I. C. Russell, to whom we are indebted for much of our knowledge of southeastern Oregon.

The Oregon Bureau of Mines and Geology, created by legislative act in 1912, has contributed several important results of investigations, more especially relating to the economic aspect of the subject, and this Bureau has given financial assistance to other work which has not appeared in its publications. The Bureau maintains offices and a display collection of ores in Portland and issues monthly *The Mineral Resources of Oregon*.

The chief contribution to our knowledge of the Blue Mountain region of eastern Oregon has been made by Waldemar Lindgren.

Not the least important among the groups of investigators of Oregon geology is the department of paleontology of the University of California, which has devoted its attention largely to the fossil beds of eastern Oregon.

The University of Oregon, represented by a line of workers such as Ellen Condon McCornack, daughter of Dr. Condon, Chester

Washburne, Arthur J. Collier, Graham John Mitchell, and others, has contributed, if not voluminously, most substantially, to the accumulated knowledge in this field.

Besides those mentioned there are several other authors who have contributed one or more papers in special fields, and these are listed in the bibliography, which includes only the more important contributions to the subject.

PHYSIOGRAPHY

The state of Oregon is only a part of the older and much larger Oregon Territory. Its situation on the great western ocean is greatly in its favor, though it is less fortunately placed than either California or Washington.

Oregon is divided by the great Cascade Mountains into two very diverse regions, western and eastern Oregon, which differ radically, at least in the later periods, in physiography (including climate), geology, economic greogaphy, and also politically, socially, and in many other ways. Western Oregon is a marine province, and its geology in part is, in common with California and Washington, similar to that of Eastern Asia, while eastern Oregon is continental and belongs to the Great Basin province. A great portion of Oregon is covered by a part of the greatest lava flow in the world, and this has had a profound influence upon its history, both geologic and economic.

Following the Committee of the Association of American Geographers[1] there have been recognized the following physiographic divisions in Oregon:

1. "*The Oregon Coast Range* is the section of the Pacific Border Province west of the Puget Trough and consisting of Tertiary rocks," sandstones, and shales cut by igneous intrusives.

2. "*The Puget Trough,* the intermontane lowland west of the Middle and Northern Cascade Mountains." In Orgeon this is known as Willamette Valley and is filled largely with alluvium, but many outliers of Tertiary sediments and buttes with Tertiary igneous intrusives are found within this area.

3. "*The Middle Cascade Mountains* are that portion of the Sierra-Cascade Province whose height is due in part to volcanic

[1] *Ann. Assoc. Am. Geographers,* VI, 34.

accumulation and in part to crustal uplift." This is a great dissected plateau. Tertiary sediments in the form of a great synclinorium pass under these Tertiary and Pleistocene lavas.

4. "*The Klamath Mountains* are the section of the Pacific Border Province adjoining the Cascade Mountains on the west and consisting of relatively old and resistant rocks." The most noteworthy feature of this region is the remarkable peneplain described by Diller.

5. "*The Oregon Lake Section* of the Basin-and-Range Province characterized by young block mountains and lake basins."

6. "*The Harney Section* is that section of the Columbia Plateau which lies south of the Blue Mountains." This is largely underlaid by Columbia lava. It is characterized by sage brush, "rim rock," and lacustrine sediments.

7. "*The Payette Section* of the Columbia plateau is the part west of the Snake River Plain, whose substratum consists in large part of lacustrine sediments (applies to northern part only)." This takes in practically all of the upper Snake River drainage.

8. "*The Blue Mountain Section* of the Columbia Plateau Province is the mountainous area entirely surrounded by plateau surface." This section extends up into the northeastern part of the state and includes the Wallowa Mountains, which are in many ways quite different from the Blue Mountains proper. The writers are inclined to make a separate section for this portion.

9. "*The Walla Walla Plateau* is that section which lies north of the Blue Mountains."

This includes most of the DesChutes River basin and that of the famous John Day Valley. This region is noted for its fine wheat lands on the plateau stretches between the rivers and for the classic fossil localities along the John Day.

The writers suggest the following slightly simplified subdivisions:

*a*) The Columbia-DesChutes Province.
*b*) The Willamette Valley Province.
*c*) The Coast Province.
*d*) The Cascade Plateau Province.
*e*) The Klamath Province.
*f*) The Blue-Wallowa Mountain Province.
*g*) The Southeastern Desert Tract.

*a*) We think it inadvisable to run a physiographic boundary across a main stream like that of the DesChutes, and suggest that a heavy line (using the scheme of the Committee of American Geographers) instead of a broken line be passed around the *head* of this river. We think Columbia-DesChutes more appropriate than Walla Walla as a name for this province.

*b*) The writers are not yet ready to subscribe entirely to the inclusion of the Willamette Valley in the Puget Sound Trough and prefer the local name.

*c*) The Coast Province may be better than Coastal Range, since all of this province is not a mountain range.

*d*) Cascade Plateau Province we think is more fitting for this dissected plateau than "Cascade Mountains."

*f*) As the Wallowa, or Eagle Creek, Mountains, as they are sometimes called, are quite distinct in some ways, yet a part of the Blue Mountains, we suggest the name Blue-Wallowa Mountains.

*g*) We would include all the territory east of the Cascades and south of the Blue Mountains in one physiographic province. This includes territory with nearly similar geology and mainly without exterior drainage. There are differences here, of course, but we think not sufficiently great to warrant such division.

The hydrography of Oregon is interesting. The state is bounded by water on almost the entire distance of three of its sides; on the west by the Pacific Ocean; on the north by the master-stream, the Columbia; on the east for more than one-half the distance by the Snake. The northern and western portions are well drained by the following streams, respectively, the John Day and DesChutes; the Rogue, Umpqua, and Willamette. The major streams in general in Oregon are northward flowing. The southeastern lava plateau and desert region is a part of the Great Basin and therefore practically without exterior drainage.

The lakes of Oregon are especially interesting both for their variety and for their diverse origins. One of these is perhaps the most famous of all the lakes of North America, namely Crater Lake at the summit of the Cascade Mountains. We note the following types, which we can only name in passing in an article of this kind:

1. The coastal lakes—type, Tsiltcoos Lake.
2. The alkali lakes of the southeastern desert region—type, Harney Lake.
3. Crater lakes—type, Crater Lake.
4. Morainal lakes—type, Wallowa Lake.
5. Cirque lakes—type, Aneroid Lake.
6. Fault block depression lakes—type, Warner Lake.
7. Lava flow lakes—many in high Cascades.

## STRATIGRAPHY

### PRE-CAMBRIAN

*Archean.*—A biotite gneiss, imbedded in the granodiorite occurring along the headwaters of the north fork of John Day River is thought to be the oldest known rock of Oregon. This metamorphic rock outcrops on the north slope of Bald Mountain, covering an area of less than fifteen square miles. There is no reason given by Lindgren[1] why these rocks are considered as being pre-Cambrian. It is true that they are similar lithologically to gneisses in Calaveras County, California, and those near Shoup and Elk City, Idaho. Since metamorphics are products of dynamic conditions irrespective of time, there is no valid reason why gneisses and schists may not be found in later ages.

*Algonkian.*—Metamorphic rocks of supposed pre-Cambrian age also occur at or near the California-Oregon boundary. Schists are found near the headwaters of Wagner Creek west of Ashland, at Starling Peak still farther to the west, and thence westward along the boundary line to Takilma, interrupted, however, by smaller masses of Paleozoic metamorphics. These areas, excepting the first mentioned, extend into California in a southeasterly direction for a distance of many miles. These rocks are variously described by Diller,[2] Winchell,[3] and others as amphibolite, hornblendite, hornblende-mica, talc, and mica-quartz schists. Since they are either continuous with, or lithologically similar to, the beds across

[1] *U.S. Geol. Surv., 22d Ann. Rept.*, Part II, p. 594.

[2] J. S. Diller, *U.S. Geol. Surv., Bull. 546*, p. 14.

[3] A. N. Winchell, *Oregon Bureau of Mines and Geol., Vol.* I, No. 5, p. 37.

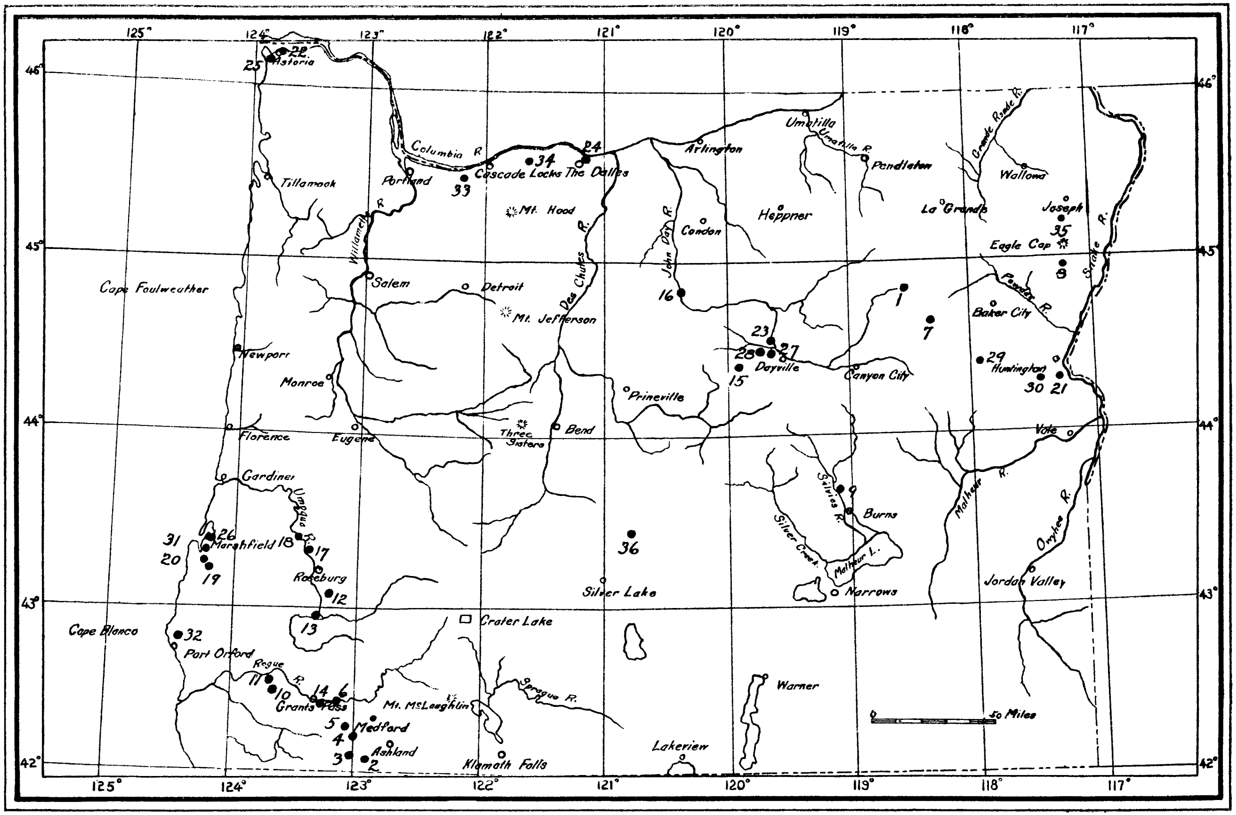



FIG. 1.—Formational locality map of Oregon: (1) Bald Mountain, Archean (?); (2) Abrams, Algonkian; (3) Salmon, Algonkian; (4) Little Applegate River, Devonian; (5) Kane Creek, Devonian; (6) Gold Hill, Carboniferous; (7) Winterville, Carboniferous; (8) Eagle Creek, Triassic; (9) Silvies River, Jurassic; (10) Galice, Jurassic; (11) Dothan, Jurassic; (12) Myrtle, Cretaceous; (13) Riddle Horsetown, Cretaceous; (14) '49 Mine, Chico, Cretaceous; (15) Spanish Gulch, Cretaceous; (16) Clarno Ferry, Eocene; (17) Umpqua River, Eocene; (18) Tyee, Eocene; (19) Pulaski, Eocene; (20) Coaledo, Eocene; (21) Payette, Eocene; (22) Astoria, Oligocene; (23) John Day, Oligocene; (24) Columbia Lava, Miocene; (25) Astoria, Miocene; (26) Empire, Pliocene; (27) Mascall, Miocene; (28) Rattlesnake, Pliocene; (29) Ironside, Pliocene; (30) Idaho Beds, Pliocene; (31) Coos conglomerate, Pliocene; (32) Elk River, Pleistocene; (33) Satsop, Pleistocene; (34) Cascade, Pleistocene; (35) Terminal moraine, Pleistocene; (36) Fossil Lake, Pleistocene.

the California boundary, which have been correlated with Hershey's,[1] Abrams, and Salmon series, it may be permissible to quote the description of the typical facies of those rocks as applicable in general to the Oregon beds:

> It [the Abrams mica schist] is composed of thin folia of muscovite of dull colors . . . . separated by irregular layers of white quartz representing the original laminae. Throughout it is very highly siliceous, and doubtless portions of it would by some be called micaceous quartz schist. In certain belts the silica predominates to such an extent as to cause it to outcrop like great veins of very glassy white and dark blue quartz.

This mica schist in California appears to grade upward through a graphite and actinolite schist to the hornblende schist series. These mica and hornblende schist series have an estimated thickness of 1,000 feet, which is no more than that developed by the first mentioned in the upper Coffee Creek section of northern California.

These old schists are in contact with the tonalite batholith at the California-Oregon boundary south of Ashland. This intrusive is of a much later date and possibly has been the dominant factor in the alteration of these sedimentary rocks to their present condition. Winchell states that these old beds are so intimately associated with intrusives as to make stratigraphic studies impossible in the vicinity of Red Mountain. The schistosity parallels the structure of the adjoining Paleozoic rocks, which have a general northeasterly strike.

Since these rocks, which were presumably originally argillaceous sandstones, or in places carbonaceous, as is testified by the graphitic schists, have been so completely metamorphosed their geologic age must be determined solely upon physical bases. The consensus of opinion seems to be that the schists at the state line are to be correlated with the Abrams and Salmon schist series of supposed Algonkian age.

### PALEOZOIC

*Devonian-Carboniferous.*—During a part at least of the Paleozoic a sea covered a portion of eastern and southwestern Oregon. Although the Paleozoic rocks outcrop in both sections, the forma-

[1] O. Hershey, *Am. Geol.*, XXVII, 227.

tions have not been differentiated, and in both regions the stratigraphy is apparently hopelessly tangled.

In eastern Oregon Lindgren[1] found an argillite series with some limestone, which at Winterville contains crinoid stems, of probable Carboniferous age. Lindgren says of these:

This argillite series is undoubtedly older than the Trias of the Eagle Creek Mountains, and may without much uncertainty be referred to the Paleozoic, possibly to the Carboniferous, which is so extensively developed in California. The whole argillite series, from Weatherby to the Greenhorn Mountains, is composed of fine-grained sediments, indicating deposition in deep waters. Sandstones, quartzites, and conglomerates are entirely absent, according to present information.

The structural features, according to Lindgren, verified to a limited extent in the field by the senior author, are quite irregular. They strike in the neighborhood of the Elkhorn Range a little north of west and dip 60 degrees south, but in the vicinity of Burnt River and Huntington they dip to the northward and strike southwesterly. No estimate of thickness of these formations, save that it may be several thousand feet, has been made.

In western Oregon there are, according to Diller[2] and Winchell,[3] about 10,000 feet of argillites, tuffs, and sandstones and limestone lenses of marine origin. This is indicated by the presence of siliceous beds containing Radiolaria.

As Winchell[4] has admirably summarized the information regarding these formations, we quote:

The Paleozoic rocks are apparently structurally conformable both with older formations and with more recent beds, but there seems to be a hiatus in deposition both before and after the period. There is no unconformity known between the formations included in the Paleozoic. Like the Jurassic, the Paleozoic beds are nearly on edge, striking northeast and dipping steeply southeast. Elsewhere in this report the writer has suggested that these beds are all overturned, so that the Carboniferous beds are structurally beneath to the northwest, and the Devonian (and Silurian ?) are above to the southeast.

The classification of these Paleozoic rocks is based on fossils found in the limestone lenses, each of which has a maximum thickness of about 200 feet and a maximum length of about 2,000 feet. They have been assigned to four chief belts.

[1] W. Lindgren, *op. cit.*, II, 578.

[2] J. S. Diller, *op. cit.*, p. 15.

[3] A. N. Winchell, *op. cit.*, p. 35, p. 26.

[4] *Ibid.*, p. 26.

Beginning on the west the first belt includes lenses on Cheney Creek, others near Kerby, and some near Waldo. In this belt fossils collected by the writer have been considered to be probably Carboniferous in age by paleontologists of the U.S. Geological Survey.

The second belt includes outcrops southwest of Gold Hill, also some west of Provolt, those at Oregon Caves, and one on Sucker Creek. So far as known no fossils have been found in this group of outcrops.

The third belt comprises the lime quarries on Kane Creek, the outcrops near Applegate, and those west of Steamboat. Fossils obtained on Kane and Steamboat creeks consist merely of fragments of round crinoid stems.

The fourth belt of lenses is found in several outcrops on Little Applegate River (and across the divide on Anderson and Coleman creeks) and in one (or more) exposures near Watkins on Applegate River. In the former well-preserved round and pentagonal crinoid stems have been found. The fossils do not definitely determine the age of the third and fourth belts, and it seems possible that they should be referred to the Silurian, or an earlier period.

These limestone lenses are of considerable importance because limestone is so scarce in Oregon that the supply for cement and other uses must be sought in them or in similar outcrops. . . . . The origin of the limestone lenses is an unsolved problem of much interest and importance.

### MESOZOIC

*Triassic.*—The Triassic is represented by sedimentaries and associated lavas reported by Lindgren[1] from the southern flank; and by Condon[2] from the northern flank of the Wallowa Mountains in northeastern Oregon. These beds are typically exposed along Hurricane Creek, Eagle Creek, and Powder River. The sedimentary members on Eagle Creek consist of calcareous shales, limestones, and agglomerates, aggregating several thousand feet. Nearer the batholitic core of the range they are altered to slates, schists and marbles. Farther west volcanic rocks, including basalts, andesites, and tuffs, comprise the dominant part of the series, while farther in the Wallowa Mountains masses of greenstone occur which may belong to this series.

J. P. Smith[3] records a section at Martin's Bridge on Eagle Creek consisting of fossiliferous shales and limestones. These are but little deformed. They yielded several species of *Halobia* and a number of corals, including *Montlivaultia* and the cephalopod *Dittmarites.* Condon obtained *Halobia rugosa* Guembel from the

[1] W. Lindgren, *op. cit.*, p. 580. [2] T. Condon, *Oregon Geology*, p. 48.

[3] J. P. Smith, *Am. Jour. of Sci.*, Series 4, XXXIII, 92–96.

north slope of the range, and W. D. Smith[1] notes fossils from near the summit of the range. These faunas are considered by J. P. Smith as representing a portion of the Hosselkus limestone of Karnic and Noric stages of Upper Triassic.

*Jurassic.*—This system is well developed in southwestern Oregon and is also known from the Blue Mountains. Recognizable Jurassic fossils were obtained by Condon[2] from Beaver Creek, a tributary of Silvies River, and from Red Butte, north of Burns. Nothing has been recorded regarding the extent or geologic relationships of these fossiliferous beds. Hyatt,[3] who examined the Condon collection, describes the matrix as a red sandstone. An examination of the specimens in the Condon Museum shows a fine-grained calcareous matrix, which is presumably an impure limestone.

The fauna includes *Peaten acutiplicatus* Meek, and *Pholadomya nevadana* Gabb as its most representative forms. These place the age of the beds as Lower Jurassic, of the Hargrave stage.

Diller[4] has shown the Jurassic rocks comprise the major portion of Oregon south and west of Rogue River. These rocks consist of sedimentary, metamorphic, and igneous rocks representing a wide range of rock types. The sedimentaries have been designated as the Galice and Dothan formations. Both formations are lithologically similar, and although now separated by a mass of greenstone and a zone of faulting the justification for separation into two formations has been questioned.[5]

The Galice formation outcrops as a band several miles in width extending northeasterly from the Oregon-California boundary. Northwest and roughly paralleling this is the type section some three miles wide and twenty to twenty-five miles long. The Dothan outcrops in a wide band still farther west and possibly extends northeasterly to the vicinity of Roseburg, Douglas County.

Both formations are composed of dark shales and slates, subordinate amounts of conglomerate, and lenses of red or gray chert. Both are steeply tilted, dipping generally to the southeast. The

[1] Smith, W. D. *Mazama*, Series 4, Dec. 1918, p. 238.

[2] C. Washburne, *Jour. Geol.*, IV (1906), 222.

[3] A. Hyatt, *Bull. Geol. Soc. Am.*, V, 401.

[4] J. Diller, *op. cit.*, Fig. 2.

[5] Winchell, *op. cit.*, I, No. 5, p. 35.

discordant dips support Diller's contention of distinct formations. Other field evidence indicates an overturning of these formations, making the Galice the older.

Marine invertebrate fossils from the Galice formation are the basis for the correlation of these beds with the Mariposa Jurassic of California. The fragmentary remains found in the Dothan resemble those from the Galice.

Franciscan Jurassic outcrops along the California-Oregon boundary for a distance of at least ten miles from the ocean shore. This region on the Oregon side, mapped as undifferentiated Jurassic by Diller,[1] undoubtedly contains Franciscan rocks. They also occur farther north in the Roseburg Quadrangle, where certain sedimentary and metamorphic rocks possibly once included within the Myrtle Cretaceous have been called the Dillard[2] and correlated upon their lithologic pecularities directly with the Franciscan. It is not improbable that these rocks connect with the Franciscan eighty-five miles farther south. Subsequent work by W. D. Smith[3] and by Davis[4] confirms the Franciscan age of these beds and adds weight to the prevailing opinion that these rocks are of Jurassic age, and that they are probably either younger or older than the Galice.

Igneous activity was pronounced during the middle Mesozoic. Various batholithic masses were intruded into the sedimentaries of British Columbia and the Coast states, resulting in regional metamorphism and often mineralization of earlier rocks, and either initiating or accompanying the uplift of the Sierras, Klamath, Blue, and Wallowa mountains.

In northeastern Oregon one or more granodiorite batholiths are now exposed as the cores of Wallowa and Blue mountains. Associated with these are diorites, gabbros, and peridotites cutting the pre-Cretaceous rocks of this region. The intrusion of the Siskiyou tonolite batholith was preceded by andesitic extrusives and intrusives, and basic rocks now largely altered to serpentines. These extensive intrusions of quartz diorite were later cut by dacite and aplite dikes. Although it is possible to determine the relative

[1] S. Diller, *op. cit.*, Fig. 2.

[2] G. D. Louderback, *Jour. Geol.*, XIII, 528.

[3] W. D. Smith, *Am. Jour. Sci.*, XLII, 299.

[4] E. F. Davis, *Univ. Cal. Publ., Bull. Geol. Dept.*, II, 40.

age of these igneous rocks, their exact geologic age is unknown, they being presumably of late Jurassic age.

*Cretaceous.*—This system is developed along the southwestern flank of the Blue Mountains, eastern Oregon, and mainly within the valleys of the Rogue, Umpqua, and Coquille rivers of southwestern Oregon. The best-known localities within the former region are Mitchell[1] and the vicinity of Antone in Wheeler County. Broad exposures are found within the Port Orford, Coos Bay, and Roseburg quadrangles, and well-recognized areas in the vicinity of Riddle, Medford, and Ashland.[2]

These rocks in part represent the Shasta-Chico series of California yielding characteristic faunas and being lithologically similar to that series. The Shasta includes the Myrtle of Diller, whose most recent definition would include even the equivalent of the lowermost Knoxville as yet unknown in Oregon.[3]

The lower Myrtle, or the Knoxville of Oregon, as found in the above-named quadrangles, is composed of shales, sandstones, conglomerates, and lenses of limestones, all of which are in places locally metamorphosed and intruded by basic rocks. Dark-blue shales so typical of the Knoxville are known in several lower Myrtle areas in southwestern Oregon as well as at Mitchell in eastern Oregon. This latter locality has not as yet yielded determinable fossils, so its correlation with the Knoxville is only tentative. Heavy Myrtle conglomerates resting upon a basement complex representing successively higher horizons indicate a transgressing sea, which condition apparently continued until the close of the period.

The upper Myrtle, containing a Horsetown fauna, is well developed in the Myrtle Creek syncline of the Roseburg and Riddle quadrangles. It is not known to occur east of the Cascades. These rocks are somewhat more variable lithologically than the Knoxville, probably being more conglomeratic.

The Chico group along Rogue River consists of several thousand feet of sediments formed in a transgressing sea, which perhaps

[1] J. C. Merriam, *Univ. Cal. Publ. Bull. Dept. Geol.*, II, 280.

[2] F. M. Anderson, *Proc. Cal. Acad. Sci.*, Series 3, II, 1–154.

[3] B. Willis, *U.S. Geol. Surv., Prof. Paper No. 71*, p. 618.

extended eastward to the Blue Mountains, where the sediments now comprising the major portion of the Cretaceous outcrops were deposited.

The rocks of the Cretaceous system represent a presumably conformable series, which everywhere lies unconformably upon a complex of older beds. Tertiary strata generally are found to be markedly discordant with the Cretaceous. A long erosion interval appears to have followed the withdrawal of the Chico sea, during which time folding and intrusions occurred, followed by erosion which removed Cretaceous sediment of unknown extent.

The igneous rocks of the Cretaceous include gabbro, basalt, dacite-porphyry, and other rocks now altered to serpentine. These cut the Myrtle group in the order mentioned.

The Knoxville fauna is meager, including the boreal *Aucella piochii* (Gabb) and *A. crassicollis* Keyserling characterizing the lower and upper Knoxville respectively. The tropical Horsetown fauna from Riddle comprises about fifteen species, several of which are known from the California Chico. The Chico of Rogue River valley, at Mitchell, and near Antone in eastern Oregon have yielded a large fauna having local characteristics, yet being closely related to the Upper Cretaceous of California and having strong affinities with the Cretaceous of the Orient.[1] As yet no marine reptiles, so well represented in the interior sea to the eastward, have been discovered in the Pacific Coast province.

Four Pacific Coast Mesozoic floras, known as the Oroville, the Oregon, the Shasta, and the Chico, have been recognized by paleobotanists and have yielded evidence as to the age of certain beds which is difficult to reconcile with that afforded by the marine invertebrates. The oldest of these, the Oroville, is from California and is thought to be Middle Jurassic or pre-Maraposa. The Oregon flora is represented by the Thompson Creek, Douglas County, locality, and consists of over one hundred species, which show close affinities with the Oölite, Middle Jurassic, yet they appear to be associated with Knoxville invertebrates which paleontologists consider as belonging to Lower Cretaceous. The Shasta fauna from Elk River, Jackson County, is certainly associated with a

[1] F. M. Anderson, *op. cit.*, p. 62.

Knoxville fauna, including a number of well-known species. The latest, or Chico, flora is not well represented in Oregon but is in closer agreement with the invertebrate faunas.

CENOZOIC

*Eocene.*—Marine Eocene is known to comprise parts of the Coast Range[1] of Oregon from Rogue River northward to the Columbia, being well developed along their western flank within the Port Orford and Coos Bay quadrangles, and along their eastern flank within the Roseburg Quadrangle. These sediments outcrop along the western base of the Cascades east of Roseburg and at several localities within the Willamette Valley.

The Eocene rocks consist of sandstones, shales, carbonaceous shales and coals, conglomerates, tuffs, basalts, and various intrusives.

The Umpqua-Arago[2] group, including the marine and estuarine deposits, may represent over 20,000 feet of sediments, which are divided into a number of formations, the exact positions in the geologic column of several of which are as yet uncertain. The oldest, the Umpqua group, is well developed on Little River, Roseburg Quadrangle, where it consists of 7,500 feet of marine sediments. This group includes the Wilbur tuff—lentils, the Umpqua formation, the Tyee sandstone, and possibly the Oakland limestone formations. The most important of these is a rather coarse-grained, thick-bedded sandstone known as the Tyee sandstone. This has been traced by Washburne[3] from Rogue River Mountain northward along the Coast Ranges into Tillamook County.

The Arago, the lower part of which may be the equivalent of a part of the Umpqua formation and the later Tyee sandstone,[4] is found within the coast quadrangles and consists mainly of sandstones and shales, some of which are coal-bearing. The older Pulaski formation also includes some fossiliferous limestone and basaltic tuffs. The younger Coaledo formation is coal-bearing, but along the eastern margin of the field includes some basaltic

[1] S. Diller, *U.S. Geol. Surv., 17th Ann. Rept.*, Part I, p. 469.

[2] *Ibid.*, Folios 49, 73, and 89.

[3] C. W. Washburne, *U.S. Geol. Surv., Bull. 590*, p. 9.

[4] R. E. Dickerson, *Proc. Cal. Acad. Sci.*, Series 4, IV, 114.

flows and diabase. Probable equivalents of the upper portion of this series are found in the Ione lacustrine deposits within the Rogue River valley.

The Eocene beds have been thrown into gentle folds, which even along the crest of the Coast Range are nowhere as steep as those developed in the Myrtle or older beds. In places normal faults have developed, the thrust fault being less frequently seen.

Eocene invertebrates occur at a number of localities. These are typical Tejon forms, including the well-known *Turritella uvasana* Gabb and *Venericardia planicosta merriami* Dickerson. The large fauna from the Little River, Roseburg Quadrangle, as shown by Dickerson, belongs to the Siphonalia sutterenses zone of upper Tejon. Since this was found some 10,000 feet from the base of the Umpqua-Arago series, and since the Arago of Diller has been by several considered later than the Umpqua formation, it may prove to be the brackish water equivalent of the Ione Eocene of California.

With the beginning of the Eocene eastern Oregon became a province, distinct both geologically and physiographically. The oldest Tertiary beds have been described as the Clarno by Merriam,[1] and named after the type locality, Clarno Ferry, Wheeler County. The formation was also recognized in the vicinity of Fossil and along the west side of John Day River, and was later extended eastward to Heppner,[2] as a strip ten to fifteen miles wide.

The Clarno is typically composed of varicolored sandstones and shales, which are in places carboniferous, grading upward into paper shales and coarse rhyolitic tuffs. In places near the bottom andesitic flows are found, while rhyolites occur nearer the top of the section.

These beds range from 400 to 2,000 feet in thickness. They have dips as high as 25 degrees, which may be locally increased upon fault blocks. The Clarno rests unconformably upon Chico Cretaceous at Mitchell and upon the Knoxville (?) shales farther west. An angular unconformity with the overlying John Day beds

[1] J. C. Merriam, *op. cit.*, II, 285.

[2] W. G. Mendenhall, *U.S. Geol. Surv., Bull. 341*, p. 406.

has yet to be reported. It is, however, presumed that a hiatus between the two will be found.

These terrestrial beds have yielded fossil plants only, which were early discovered at Bridge Creek by Condon. The flora, as determined by Knowlton, comprises about twenty-five forms, which indicate the Eocene age of the formation. There is some evidence that both the lower and upper Eocene floras are represented.

In Malheur and Harney counties a series of sedimentary beds occupies, in part, the Snake River Valley from a point near Owyhee northward to Ontario, extending westward to a locality some thirty miles southwest of Vale.

These beds consist mainly of unconsolidated gravels, sands, clays, and volcanic ash. Similar beds along Snake River in Idaho have been described by Lindgren[1] as the Payette formation. He ascribes their origin to a large Neocene lake, but Russell[2] inclined to the belief that the Oregon beds were of fluvatile origin. These may well include other Tertiary strata, as Washburne[3] suggests, and as is apparently proved by Merriam[4] by the discovery of the Ironside formation at Ironside. The fossil leaves and fresh-water mollusks indicate an early Tertiary age for these beds. The Payette has been correlated with the Ione, Upper Eocene of California, upon the basis of fossil plants, and with the Upper Clarno of the John Day Valley by Merriam. If it is the equivalent of the Upper Clarno the sedimentation was much more rapid in the Payette Basin.

*Oligocene.*—Certain marine beds at Astoria, well known through the early work of Dana, Conrad, and Condon, were the first of the entire coast to be assigned to the Oligocene. The basis upon which the correlation was first made by Dall has not as yet been discussed. This Astoria section now serves as the type section for the west-coast Oligocene, which is now known to be well developed in the adjoining states.

In Oregon, Oligocene faunas have been identified by Clark[5] and others from a number of localities, mainly in Clatsop, Columbia,

[1] W. Lindgren, *U.S. Geol. Surv.*, Folio 103, p. 2.

[2] I. C. Russell, *ibid.*, *Bull. 252*, p. 31.

[3] C. Washburne, *ibid.*, *Bull. 431*, p. 27.

[4] J. C. Merriam, *op. cit.*, X, 111.

[5] B. L. Clark, *Univ. Cal. Publ.*, *Bull. Dept. Geol.*, II, 102.

and Tillamook counties, and at Eugene, Lane County. These and other less well-known localities indicate that the Oligocene is quite extensively developed throughout northwestern Oregon, eastward to the foothills of the Cascades, and at least as far south as Eugene. Much remains to be done in connecting, or correlating, these rather isolated areas.

These Oligocene strata, aggregating several hundred feet, consist of marine shales, sandstones, conglomerates, tuffs, and basaltic intrusives, varying considerably in character from locality to locality.

The Oligocene marine fauna of Oregon is but imperfectly known, the *Molopophorous lincolnensis* and the *Acila gettysburgensis* zones of Washington being certainly recognized.

The upper Oligocene is well developed within the John Day Valley, where some 1,500 feet of sedimentaries are known as the John Day series. It is well exposed along the valleys of the John Day from Picture Gorge to Clarno, and along the North Fork to a point some distance above Monument. Other isolated localities are known outside the John Day drainage basin. The series is divisible into three lithologic and paleontologic divisions, the lower of which is characteristically composed of red, green, or white shales; the middle division by drab and bluish tuffs; and the upper by buff tuffs, rhyolite, sands, and gravels. These terrestrial beds are but little deformed, dips of 5 to 10 degrees being rather exceptional.

The remarkable vertebrate fauna is confined to the two upper divisions, the middle yielding a *Diceratherium* zone fauna of over fifty species. The upper fauna is that of the *Promerycochoerus* zone. This John Day fauna of over one hundred species is correlated with the upper portion of the White River group.

*Neocene.*—The Neocene of western Oregon is represented by a series of sedimentaries yielding a lower or Monterey fauna, and an upper or Empire-Merced fauna. The beds yielding the Monterey fauna have not as yet been clearly differentiated from the Astoria group, so that their distribution and geologic characteristics can be given only in the most general terms. They include, in part, the "Solon Beds" of Condon. The strata at these localities con-

sist of marine sandstones and shales of as yet an undetermined thickness.

An invertebrate Monterey fauna is reported by Arnold and Hannibal[1] from Astoria, Mountain Dale, Westpoint, Tillimook, and along the ocean shore in the vicinity of Newport. Much, if not all, of the reported Miocene in the Coast Ranges and the Willamette Valley is now assigned to the Oligocene. A fauna of over thirty species has been obtained by Hannibal at Astoria, including *Arca devincta* Conrad, *Pecten propatulus* Conrad, *Turritella oregonensis* Conrad. These are thought by him to be characteristic of the Monterey of California, which is of lower Miocene age. Marine vertebrates, including *Desmostylus hesperus* Marsh, and *Desmatophoca oregonensis* Condon, have been found in these beds in the vicinity of Newport. These important fossils point to a middle Tértiary age of these beds.

The upper Neocene beds were described by Diller[2] as the Empire and assigned to the Miocene. They are known from the Coos Bay and Port Orford quadrangles, where they consist of light-colored shales and sandstones, which are in places massive. These rocks, aggregating about five hundred feet in thickness, lie unconformably upon the folded edges of the Eocene sediments, and in turn are disconformable with the overlying Pleistocene deposits.

Dall's[3] list of 90 species of marine vertebrates from the Empire has been considerably extended by subsequent workers. This formation until recently considered of Miocene age is now thought to belong to the early Pliocene.[4]

Unconformably overlying the Empire beds at Fossil Point, Coos Bay, is a mass of heavy conglomerates known as the Coos conglomerates, some thirty feet in thickness, which has yielded a small marine fauna, considered Pleistocene by Dall,[5] but Pliocene by several other workers.

Terrestrial beds discovered by LeConte and more recently described by Williams[6] as the Eagle Creek formation occur at or near

[1] R. Arnold and H. Hannibal, *Proc. Am. Phil. Soc.*, LII, 576.

[2] J. Diller, *U.S. Geol. Surv., 17th Ann. Rept.*, Part I, p. 475.

[3] W. H. Dall, *U.S. Geol. Surv., Prof. Paper 59*, p. 18.

[4] B. L. Clark, and R. Arnold, *Bull. Geol. Soc. Am.*, XXIX, 298.

[5] W. H. Dall, *op. cit.*, p. 19.

[6] I. A. Williams, *Mineral Resources of Oregon, Oregon State Min. Bur.*, II, 80.

the base of the Columbia lavas at Eagle Creek, Multnomah County. This formation consists of hardened ashy clay and has yielded a flora of over forty species, which is thought to be of upper Miocene age. Such a determination would place the Columbia lava in the late Miocene, or Pliocene, which is contrary to the evidence afforded by the Mascall fauna, which occurs within the John Day Valley and has yielded an extensive middle Miocene fauna.

Unfortunately this name is preoccupied by the Triassic Eagle Creek beds of the Wallowa Mountains. The Miocene formation might well be called the Warrendale formation, from the town of that name, near Eagle Creek, a tributary of the Columbia.

W. D. Smith[1] has described a series of at least four hundred feet of buff-colored tuffs occurring on the Santiam River near Cascadia, which may be correlated with the Warrendale formation, or possibly with the John Day. As yet no fossil remains have been found in these tuffs.

Lying above the Warrendale formation, which may later prove but a local interbedded deposit, is the Columbia lava, a name applied by Russell to basaltic flows occurring extensively in eastern Washington and redefined by Merriam[2] to include only the lavas younger than the John Day Oligocene and older than the Mascall middle Miocene. As thus defined the Columbia lava is a widespread formation covering large areas in eastern Oregon, eastern Washington, western Idaho, and northern California, entering into the structure of the Oregon Cascades as shown by Diller, Williams, and Smith, and occurring presumably in discontinuous areas of western Oregon.

The Columbia lava series consists of basaltic flows, often interbedded with lateritic deposits and tuffs. These vary considerably from place to place as regards number and thickness. Twenty-three have been counted on the John Day and twenty in the Columbia gorge.

East of the Cascades these flows are often but comparatively little deformed, though in places they have been faulted, resulting in the typical block-fault type of mountains. In some places this

[1] W. D. Smith, *Univ. of Oregon Bull. 16*, p. 38.

[2] J. C. Merriam, *op. cit.*, II, 304.

apparent folding may be due to pre-existing irregular topography. Along the Columbia River gorge the flows are seen to be thrown into an anticlinorium.

The age of this series of flows is definitely limited by the middle Miocene Mascall and the John Day Oligocene.

Beds unconformably overlying the Columbia lava within the John Day Valley have been named the Mascall formation.[1] These beds, aggregating about one thousand feet, consist of conglomerate, sand, ash, and tuff, and have yielded a rich vertebrate fauna and a well-defined flora,[2] of middle Miocene age.

The Pliocene of eastern Oregon is represented by the Rattlesnake,[3] Ironsides, and Idaho beds. The oldest of these, the Rattlesnake, is typically developed on Rattlesnake Creek, near the Mascall Ranch on John Day River. These beds have been recognized by Osmont in the Crooked River Valley. The Rattlesnake consists of coarse basal gravels, brown tuff, and a rhyolite flow. This formation has been deformed and in places faulted. Its vertebrate fauna, though meager, is sufficient to indicate an early Pliocene age.

Sedimentary beds at Ironside,[4] Malheur County, have recently been designated the Ironside formation. Buff-colored, sandy shales and shales of possibly two hundred feet in thickness, now deformed, yielded a small vertebrate fauna which Merriam considers as being younger than the Rattlesnake Pliocene.

Lindgren[5] has described certain lacustrine deposits along Snake River as the Idaho formation. This has not been distinctly separated structurally and lithologically from the earlier beds of the same region known as the Payette, though the presence of equine and proboscidian remains prove the presence of later beds.

PSYCHOZOIC

*Pleistocene.*—The Pleistocene of Oregon includes lake, glacial, and river deposits, marine conglomerates, sands, peat, and extensive igneous formations. It is yet too early to put all these widely

[1] J. C. Merriam, *op. cit.*, II, 305.

[2] F. H. Knowlton, *U.S. Geol. Surv., Bull. 204*, 1902.

[3] *Op. cit.*, p. 310.

[4] J. C. Merriam, *op. cit.*, X, 129.

[5] W. Lindgren, *U.S. Geol. Surv.*, Folio 103, p. 2.

separated and heterogeneous materials in their proper chronological order.

At many points along the Oregon coast, but especially well developed at Cape Blanco, we find marine conglomerates, sands, and shell beds lying unconformably above the Empire (Pliocene) and nearly horizontal, but with a slight southerly dip. The section at Cape Blanco is described and figured by Diller.[1]

There are two distinct horizons above the Empire here, the lower one being presumably the Cape Blanco beds of Diller which Dall has suggested may correspond to the Merced of California and hence Pliocene. The upper part with recent-looking shells is Pleistocene, without much doubt. These have been called the Elk River beds, which Arnold and Hannibal[2] correlate with the Saanich formation of Puget Sound. These investigators do not appear to make any separation of the beds overlying the Empire.

Diller notes a lithologic difference between the Blanco and the Elk River beds, chiefly in the matter of consistency. This may be of little significance. Similar Pleistocene marine deposits can be seen in similar position all along the Oregon coast to the Columbia River.

From a consideration of the above-mentioned deposits we are led to discuss the Satsop formation of Bretz,[3] in which this investigator includes some at least of these coastal gravels. His type locality for this formation is in the Chehalis Valley, Washington, and the formation is especially well represented in Oregon along the Sandy, a tributary of the Columbia River, near Portland. Bretz's description of this formation along the Sandy is as follows:

> The formation is at least 600 feet thick along the Sandy River, with the base below river-level. The material is stream-bedded gravel and sand, indurated in some places to a conglomerate and sandstone. Quartzite is a common constituent for 10 miles south of the Columbia, but has not been found more than 15 miles from the master-stream. Quartzite and basalt are the most important constituents.
>
> The Satsop formation of the lower Willamette Valley is maturely dissected, the dissection adjusted to a base-level 200 feet or more above present flood

[1] J. S. Diller, *U. S. Geol. Surv., Bull. 196*, p. 31.

[2] R. Arnold and H. Hannibal, *op. cit.*, LII, 508.

[3] J H. Bretz, *Jour. Geol.*, XXV, No. 5 (1917), 446–59.

plains. This level is recorded in the major valleys by a prominent terrace developed mostly in the Satsop formation but in places cut in the underlying basalt. This is the Cowlitz Terrace already described.

The uplands of this Satsop plain bear a red clay soil 10–15 feet deep. This grades down into a much-decomposed gravel. At a depth of 30 feet the pebbles are decayed only on the exterior. Below 50 feet most of the material is hard and ringing when struck with the hammer. Near the Columbia the clayey residual soil on the top of the Satsop formation contains scattered quartzite pebbles, hard, bright, polished, and apparently unaffected by the weathering which has reduced the associated basaltic pebbles to a structureless clay.

The present writers have examined this formation along the Sandy and the Columbia rivers near Crown Point, but have not traced it over anything like the territory covered by Bretz. Wherever they have seen it the formation appeared to be an ordinary river gravel plastered against the sides of the valleys and on benches above the present stream beds. We did not see it disappear under the andesitic lavas at any point, though we are not prepared to say that is may not do so. A deposit of gravel might very easily be laid down underneath an undercut cliff and in this way give one the impression of having been laid down first, with a lava flow rolling out on top of it later.

With these river gravels Bretz correlates, by taking a long jump, the gravels already referred to, occurring at Cape Blanco and Elk River. He also suggests the inclusion of the quartzitic gravels in eastern Oregon at The Dalles. Why not go farther east to the John Day country, where the Rattlesnake formation (Pliocene) is found to contain many quartzitic pebbles! As yet no fauna has been found in these Cascade gravels.

Fossil leaves were found in this formation by J. B. Winstanley, of Portland, and collections were made by R. W. Chaney, of the University of Chicago. Of these I. Williams,[1] in his Columbia Gorge paper, says:

> The fossil horizon is exposed three-fourths of a mile back from the Sandy River road, in the south side of the canyon of Buck Creek 25 feet above the water, beneath an overhanging cliff of conglomeratic phase in which pebbles of polished quartzite are common. Mr. Chaney states that in this one exposure of the Satsop, four genera and at least seven species of plant life are represented.

[1] I. Williams, *Ore. Bur. Mines and Geol.*, II, No. 3

They include the oak, willow, walnut, and the sequoia. The latter is apparently the living redwood of California. Both the oak and the willow likewise closely resemble their living relatives in that sister-state at the south.

There are in this Satsop flora above the Columbia basalt remains of several of the same genera found in the Eagle Creek strata below that great body of lava, but their specific characters are so markedly more modern as to brand this flora at once as belonging to a distinctly later age. On the other hand, this flora includes plants that at present grow upon the earth, most of them, however, flourishing only in the warmer climate of lower latitudes. Such equivalence to living forms might imply enforced migration, the retrieval of lost territory having not yet, to the present, been made. Or more likely, that the climate in which they grew, and prior to their displacement, was a more equable one than ours of today. In any case, similarity with land plants found elsewhere in undoubted Pleistocene strata, as well as with those of the present, affords us tentative grounds at least for saying with added confidence that the Satsop formation, as it enters into the structure of the Cascade Range, appears to belong to the Pleistocene.

The deposits at Fossil Lake and at other lakes of the semiarid region of south-central Oregon are definitely referred to the Pleistocene. First it should be stated that the avifauna and equifauna mentioned in the literature in connection with Silver Lake came from Fossil Lake a few miles northeast of Silver Lake. As there are two Silver Lakes in south-central Oregon, the name Fossil Lake ought to be used to the exclusion of that of Silver Lake.

This lake is now dried up, and the surface material consists of a light-colored mixture of sand, clay, and silts. Some of this may be a fine-grained tuff. Deposits of tufa, or lime carbonate, are found covering much of the surface about these lakes.

We cannot refer these deposits to their proper zone at the present time. In these same beds containing Pleistocene animals there were some human artifacts, chiefly arrowheads, which it is thought are of more recent origin.

Extensive and highly important collections, principally of birds and horses, have been made here by various institutions, Dr. Thomas Condon being the first scientist to explore them. The most notable studies made on this subject are by Schufeldt[1] and by Cope.[2] Many bones of the mammoth, of camels, and horses

[1] R. W. Schufeldt, *Jour. Acad. Nat Sci.*, Philadelphia (1892), No. 9.

[2] E. D. Cope, *Am. Natural.*, XXXIII, 970-82.

(*E. pacificus*) from this locality are in the Condon Museum at the University of Oregon. A flamingo is perhaps the most striking feature of this fauna. Schufeldt thought that these deposits were of Pliocene age, but Osburn and others have shown that they must be early Pleistocene.

Above the Columbia lava and the Satsop is the great pile of more recent lavas in the Cascade Range which have been found to be predominantly andesitic. A part of this series of several thousand feet of thickness is undoubtedly Pleistocene, but the lowest portion may be Pliocene and the upper portion may be Recent. These lavas make up the bulk of the several more or less eroded cones, such as Hood, Jefferson, Three Sisters, and McLoughlin, which rest upon the Cascade basaltic lava plateau.

No comprehensive article or book has been devoted to the subject of glaciation in Oregon, and very few papers of any kind have discussed it. On the highest mountains in the state, in the Wallowa Mountains and the Cascades, there are mere remnants of one-time large glaciers, and these are relatively unimportant. We have never seen a catalogue of the glaciers in Oregon and do not know exactly how many there are. In the Wallowa Mountains there is only one glacier of any consequence, and it is not large. On Mount Hood there are eight, on Jefferson four, and on Three Sisters eleven. How many there are on Mount Washington is not known. Mount McLoughlin is too far south, we believe, and not of sufficient height to have much ice upon it.

Though the existing glaciers are small in Oregon (the largest, Collier Glacier on the Sisters, being not over a mile in length) they were once much more extensive, for their despoits are found at much lower elevations.

Every class of glacial deposit characteristic of alpine glaciers can be found within the limits of the state. The largest moraine the writers have seen is the lateral moraine on the east side of Wallowa Lake in the extreme northeastern part of the state. This is about six miles long, one-fourth of a mile wide, and between six and seven hundred feet high. It is fivefold at its lower end.

Perhaps the most interesting and at the same time most puzzling phenomenon connected with the subject of glaciation in Oregon is

the erratics of granite, quartzite, and argillite to be found here and there in the Willamette and adjacent valleys in western Oregon. One of these erratics is a polished and striated quartzite bowlder about the size of one's head. The striations are unmistakably of glacial origin. Their presence has been explained, perhaps correctly, by Condon as having been dropped from icebergs floating in the "Willamette Sound." It is difficult to explain the presence of these on any other basis, as they could hardly have been brought down from the upper Willamette Valley, since no such rocks have yet been found near the headwaters of that system of drainage. However, all these rocks are found in eastern Oregon, whence they might have been transported by the Columbia.

There was undoubtedly a large body of water occupying at least the lower portion of the Willamette Valley, but this, as both Dr. Condon and his daughter, Mrs. McCornack, expressly stipulate, was in part fresh. Thus the use of the term "sound" is perhaps unfortunate. The flatness of the floor of the Willamette Valley has been attributed to the presence of this sound, but is more easily explained by aggradation and the lateral planation by the river.

A fauna from scattered localities within the Willamette Valley has been reported by Mrs. McCornack.[1] The interpretation of this fauna, which includes a horse, a bison, a mammoth, and a camel, may have an important bearing upon the "Willamette Sound" and the "Satsop" problems.

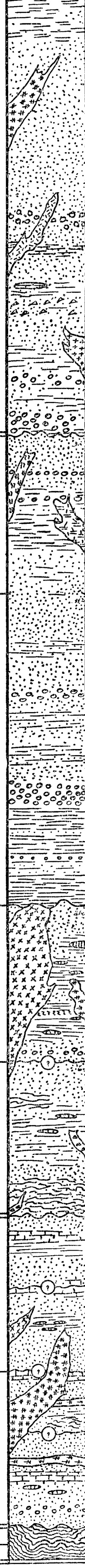
*Recent.*—Among the forms of deposits and events of the Recent period in Oregon we may note the following:

1. Gravels—stream, ocean littoral.
2. Talus—on the valley sides.
3. Dunes along the coast and in lake region of eastern Oregon.
4. Peat bogs in the coastal dune area.
5. Volcanic deposits in the Cascades.
6. Shore deposits, beaches, bars.

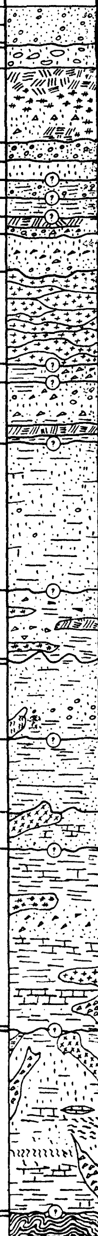
This list does not pretend to give the chronological sequence, about which there is more or less conjecture. Some of these undoubtedly are synchronous. About the first two little need be said, as these are found everywhere.

[1] Ellen Condon McCornack, *Univ. Ore. Bull.*, XII, No. 2 (1914), 13.

| Era | System | Group or Series | Formation | Section | Lithology | Correlatives |
|---|---|---|---|---|---|---|
| Cenozoic | Recent | | Alluvium | 61195 | Sands and gravels | |
| | | | Volcanics | 61145 | Rhyolitic flows, pyroclastics | |
| | Pleistocene | | Terrace | 60145 | Sands and gravels | Saanich |
| | | | Elk River | 60120 | Shales, sands and gravels | San Pedro (?) |
| | Pliocene | Merced | Coos Conglomerate | 60030 | Conglomerate | Merced |
| | | | Empire | 60000 | Sandstone and shales | |
| | Miocene Lower | Monterey | "Solen Beds" in part | 59500' | Shales, sandstones, basaltic flows (?) | Monterey |
| | Oligocene | Astoria | | 57500' | Shales, tuffaceous shales, and basaltic intrusions. | San Lorenzo (Clark) |
| | Eocene Upper | Arago-Umpqua group | Coaledo, Pulaski, Tyee sandstone, Umpqua and Wilbur formations | 56000' | Sandstones and light colored coal seams. Sandstones, shales, basaltic intrusions. Impure limestone, massive micaceous sandstones and shales, andesitic intrusions. Conglomerates, sandstones, shales, limestone lenses, tuffs, and intrusions of diabase. | Ione<br>Tejon |
| Mesozoic | Cretaceous Upper | Chico | Chico | 36000 | Sandstones and shales with interbedded conglomerates, intrusions of serpentine and gabbro cutting the Cretaceous rocks | Chico |
| | Cretaceous Lower | Myrtle | Horsetown | 31000 | Conglomerates, sandstones, and sandy shales. | Horsetown |
| | | | Knoxville | | Dark shales, thin bedded sandstones and conglomerates. | Knoxville |
| | Jurassic | Dothan | | 21000 | Granodiorite bathyliths, argillite, shale, sandstone, radiolarian cherts, intrusives, andesites, and serpentines. | Franciscan (?) |
| | | | | 16000' | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Cenozoic | Eocene Upper | Arago-Umpqua group | Coaledo, Pulaski, Tyee sandstone, Umpqua and Wilbur f |  | | intrusions. Conglomerates, sandstones, shales, limestone lenses, tuffs, and intrusions of diabase. | Tejon |
| Mesozoic | Cretaceous Upper | Chico | Chico | | 36000 | Sandstones and shales with interbedded conglomerates, intrusions of serpentine and gabbro cutting the Cretaceous rocks | Chico |
| | Cretaceous Lower | Myrtle | Horsetown | | 31000 | Conglomerates, sandstones, and sandy shales. | Horsetown |
| | | | Knoxville | | | Dark shales, thin bedded sandstones and conglomerates. | Knoxville |
| | Jurassic | Dothan | | | 21000 | Granodiorite bathyliths, argillite, shale, sandstone, radiolarian cherts, intrusives, andesites, and serpentines. | Franciscan (?) |
| | | Galice | | | 16000 | Argillites, shale, sandstone | Mariposa |
| Paleozoic | Carboniferous | | Waldo-Kerby beds Gold Hill-Oregon Cave beds. | | 11000 | Argillites, sandstones, cherts, limestones. | |
| | Devonian | | Applegate-Kane Creek beds Little Applegate-River beds | | | Tuffs, andesitic flows and intrusives | |
| Proterozoic | Algonkian (?) | | Salmon | | 1000 | Hornblende schists | Colebrooke schists (?) |
| | | | Abrams | | 500 | Mica schists | |

GEOLOGIC COLUMN OF WESTERN OREGON



| Era | System | | Group or Series | Formation | Section (1) | Lithology | Correlatives |
|---|---|---|---|---|---|---|---|
| | Recent | | | Alluvium | 30700' | Sands and gravels | |
| | | | | Terrace deposits | 30650' | Sands and gravels | |
| Cenozoic | Pleistocene | | | Glacial deposits | 30600' | | |
| | | | | Cascade | 30000' | Andesitic and rhyolitic flows, dacite and tuffs. | |
| | | | | Satsop | 28000 | Sands and gravels. | Satsop |
| | | | | Fossil Lake beds (2) | 27400' | | |
| | Pliocene | Upper | | Idaho beds | 27350' | Sands, gravels clays | Idaho formation |
| | | | | Ironside beds | 27150' | Buff sandy shales | |
| | | Lower | | Rattlesnake | 26950' | Tuffs, gravels and rhyolitic flows | Procamelus zone |
| | Miocene | Middle | | Mascall | 26650 | Tuffs, ashes, and possibly gravels | Merychippus zon |
| | | Lower | | Columbia Lava | 25650' | Olivine, basalts, tuffs, and intercalated gravels. | Yakima basalt |
| | | | | Warrendale (3) | | Carbonaceous clays and tuffs | |
| | Oligocene | Upper | John Day | John Day | 22650 | Tuffs, sands and gravels, rhyolite. Drab and bluish tuff Red, green, & white shales, rhyolite. | Promerycochoerus Diceratherium zon |
| | Eocene | Upper | | Payette | 21000' | Sands, clays, and fine gravels. | Payette of Idaho |
| | | Lower | | Clarno | 17000' | Shales, tuffs, rhyolitic and andesitic flows. | Manastash formati |
| Mesozoic | Cretaceous | Upper | Chico | Chico | 15000' | Sandstones, conglomerates and shales. Serpentine intrusions. | Chico |
| | | Lower | Shasta | Knoxville (? | 13000' | Dark bluish, fine grained shales and sandstones | Knoxville (?) |
| | Jurassic | Lower | | Silvies River beds | 11000' | Bathylithic intrusions, granodiorite. Red impure limestone | Hargrave |
| | Triassic | Upper | Eagle Creek series | Eagle Creek beds | 10050 | Calcareous shales, limestones, agglomerates, basalts, andesites, and tuffs. | Hosselkus limestone |
| Paleozoic | Carboniferous | | | Big Creek, Winterville, and Crooked River. Crook County. | 5500' | Dark colored argillites, cherts, clay slates, limestone lenses, greenstone, diorite, and gabbro intrusives. | ? Delhi formation of Calaveras |
| Archeozoic | Archean (?) | | | Bald Mt Gneiss | 500' | Gneiss | |

FIG. 2.—Geologic column of eastern Oregon

(1) These thicknesses are in most cases only approximations.

(2) The relationship to the Satsop is unknown.

(3) The relationship to the John Day is unknown.

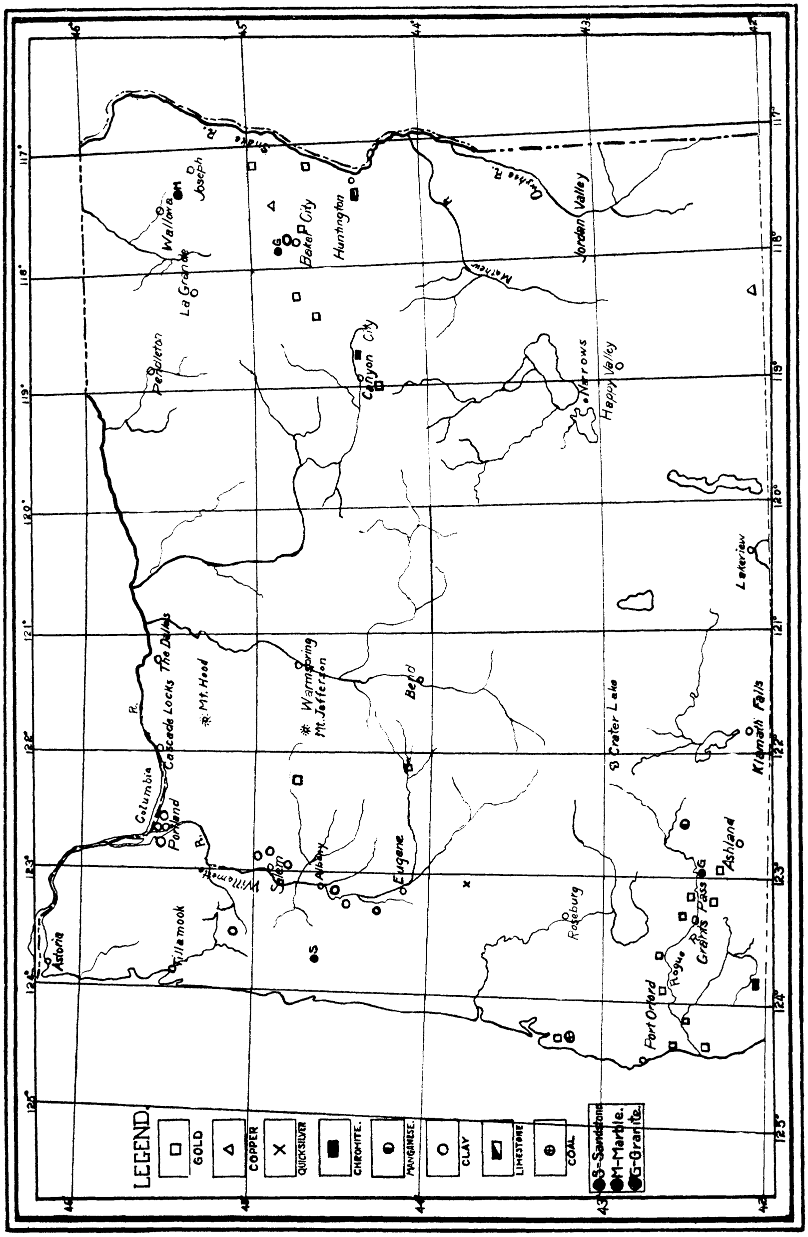



FIG. 3.—Principal mineral localities in Oregon

In the topography of the Oregon coast dunes are especially noteworthy, since Neocene and Pleistocene sandy formations outcrop throughout practically its whole length. These shifting sands have, besides resulting in dunes, caused the formation of a chain of very interesting and picturesque lakes. These lakes owe their existence to the damming up of sluggish streams by the shifting ocean sands.

Peat bogs are now forming in these dune areas, where large quantities of sphagnum moss and rhododendron leaves accumulate. In the cliffs overlooking the sea, near the top of the section in many places can be seen a bed of two feet or more of fairly solid peat. This may be of Pleistocene or Recent age, or in part both.

In various parts of the Cascades there are cinder cones and lava streams which have every appearance of being of very recent origin. Some of these may be not much over a hundred years old. Indeed very carefully sifted newspaper stories and accounts by pioneers make it reasonably clear that volcanic activity persisted in the Cascade region until a very late day. The *Portland Oregonian* reports an eruption from Mount Hood as late as 1865.

## GEOLOGIC HISTORY

The basement, upon which the Oregon strata appear to lie may be represented by the Bald Mountain gneiss of the Blue Mountains. The chemical composition of this supposed Archean rock indicates a sedimentary origin. Similar gneisses in Idaho and California possibly suggest a wide extension of a sedimentary terrain subsequently removed by erosion, or covered by younger deposits.

In the late Proterozoic southwestern Oregon became a basin of deposition in which the presumably conformable Abrams and Salmon formations were developed. This epoch of sedimentation was followed by a period of folding and accompanied by metamorphism which altered these rocks to mica and hornblende schists. An erosional interval extending over several geologic periods preceded the depression, in the middle Paleozoic of this same region, allowing the sea to enter from the southwest. The earlier sediments of this marine basin, now tentatively assigned to the Devonian system record a transgressing sea, with frequent oscillations from deep to shallow waters. Little is known regarding the climatic

conditions in Oregon, yet judging from other evidences these seas elsewhere teemed with corals, indicating tropical conditions. By Carboniferous time this, or a later sea in which crinoids lived, also covered a portion of the Blue Mountains of northeastern Oregon, which approximately marks the easternmost extension of that arm of the sea. The presence of tuffs and vesicular lava in the southwest gives a glimpse of volcanic activity upon the adjacent land mass.

Continental movements culminating in the Appalachian revolution caused a general retreat of the oceans to the outer edges of the continental shelf. In Oregon the Paleozoic sediments of both the southwest and northeast were uplifted, folded, and somewhat metamorphosed, though the principal orogenic movements of the Klamath region may have occurred later.

A long erosion interval followed, longer perhaps in the southwest than in the Wallowa Mountain region, for there the record of a shallow, oscillating sea, with a shore line not far to the southeast, is found in the Eagle Creek series of Triassic age. The meager fauna suggests little of the probable mild climate that prevailed.

During the Triassic and the earlier Jurassic the Klamath region of California and Oregon was probably land, and is thought by Diller to have been the scene of vigorous volcanic activity, the record of which is still seen in California along the southern margin of that land mass. If an early Mesozoic sea ever covered that region its record is yet to be discovered.

A few lower marine Jurassic fossils from the southwestern flank of the Blue Mountains is the only record of the Jurassic of eastern Oregon. This sea, skirting the slowly rising Blue Mountains probably did not extend far into Idaho, and it may have received the sediments from a great westward-flowing stream occupying the Snake River valley of Idaho.

Late in the Jurassic an epoch of sedimentation, known as the Galice, was again initiated in southwestern Oregon by the development of a basin in which diverse marine and possibly terrestrial beds accumulated. The meager fauna from these or even later Jurassic beds in Oregon tells little of the probable boreal aspect of

these seas. In California this boreal sea followed the warmer one of the Middle Jurassic, in which reef-building corals abounded.

It is not unlikely that minor diastrophic movements intervened between the close of the Galice and the opening of the Dothan-Franciscan time. During this succeeding epoch sediments accumulated in a basin in part coextensive with that of the Galice. Some of these were terrestrial deposits developed under arid conditions, while others point to the not infrequent recurrence of marine conditions. That the climate was more humid and warmer during at least a part of this epoch seems to be vouched for by the remarkable flora obtained from Nichols, Douglas County, Oregon, which includes cycads, ferns, ginkgoes, and conifers. This remarkable flora is said to be the richest of that obtained from any Mesozoic locality.

This period of sedimentation was followed by a great mountain-building epoch at or near the close of the Jurassic, resulting in the uplift of the Sierra, Klamath, and Blue mountains to greater altitudes than they had yet attained. These movements resulted in folding and faulting of the strata involved, and were accompanied, if not caused, by the intrusion of the Siskiyou tonolite batholith, and other types of igneous rock in the southwest, giving the main structural features to the Klamath Mountains as well as greatly metamorphosing many of the rocks involved.

In eastern Oregon "after the deposition of the Trias followed another and more extensive uplift, probably the same which affected the whole of the Pacific slope. Both the Triassic and Paleozoic series were folded . . . . the Trias were violently compressed in the area now occupied by the Wallowa Mountains. The uplift was accompanied by very extensive intrusions of granular rocks."[1] Thus the Blue Mountains in late Jurassic and Cretaceous times must have been a range of imposing height having a general eastward and westward trend.

The principal metallic deposits of southwestern and northeastern Oregon are genetically related to these igneous intrusives. The earlier epoch of mineralization occurring in the Paleozoic was of

[1] W. Lindgren, *U. S. Geol. Surv., 22d Ann. Rept.*, p. 596.

lesser importance. The latest occurred after the extrusion of the Columbia lava in the Miocene, followed by late Tertiary and Quaternary concentrations as placers or secondary enrichments.

Marine conditions were again initiated in later Knoxville time by the advance of an arm of the sea along the northern flank of the then partially dissected Klamath Mountains. The erosion preceding and continuing into this epoch had partially lowered those mountains and had exposed rich quartz lodes to the actions of the streams. Gold was thus washed out and deposited in the basal gravels of the transgressing Cretaceous sea. By upper Knoxville time the cold sea-waters of that time were cutting in the Franciscan rocks near Roseburg and were possibly skirting the foothills of the Blue Mountains. The meager boreal fauna of this sea gave way to the abundant tropical life of the Horsetown Sea, which was coextensive, in southwestern Oregon at least, with that of the preceding epoch. A rich Shasta flora upon the adjacent land gives another glimpse of the forests of Oregon.

In Chico time the sea, still teeming with tropical species of Indo-Pacific affinities, entered the Rogue River basin and ultimately reached the foothills of the Blue Mountains, possibly connecting through the ancient Lassen Strait with a California sea forming the Siskiyou Island of Condon.

This marine epoch was brought to a close by the epeirogenic and orogenic movements of the Laramide revolution, resulting in the final withdrawal of the sea from eastern Oregon, the uplift of the Klamath region, the folding and faulting of the strata, and the intrusion by basic igneous rocks. It is not improbable that a minor uplift along the axis of the present Cascades occurred at that time, forming an effective barrier to the earlier Tertiary seas. A long interval of erosion followed, which is in part represented in California by the Martinez Eocene. During this time much of the Cretaceous sediment was carried away, and southwestern Oregon was reduced to a region of low relief before the next depression in western Oregon admitted a tropical Tejon Eocene sea over western Oregon as far south as Roseburg and the mouth of the Rogue River. Thousands of feet of silts and sands were deposited in this shallow sea, which at times retreated locally, permitting the

swampy conditions now indicated by seams of coal. Volcanic activity again broke forth, producing basaltic and diabasic masses, some of which still form conspicuous heights of the northern Coast Range.

The Klamath region was being still lowered by erosion, and fluvatile and lake deposits equivalent in part to the Ione Eocene were formed in local basins. Along the western flanks of the Blue Mountains considerable thicknesses of rhyolitic ash and andesitic flows of the Clarno Eocene suggest the presence of volcanic vents to the westward. Still farther east along the Idaho-Oregon boundary local changes in drainage, due perhaps to blocking of channels by lava flows, or faulting, caused the deposition of the stream and lacustrine deposits of the Payette. These terrestrial beds give evidence of a tropical flora the remains of which, accumulating in various terrestrial and estuarine basins of the state, have since changed to the valuable coal seams of the Pacific Coast.

Only slight deformative movements intervened between the Clarno Eocene and the John Day Oligocene of eastern Oregon, but in the southwest an uplift occurred at the close of the Eocene that inaugurated the conditions which during the two succeeding geologic periods produced the Klamath peneplain. In the meantime the Eocene marine sediments had been gently folded, and the northwestern portion of Oregon was again depressed, allowing the Oligocene sea to reach the region of the present site of the Cascades and extend southward at least to Eugene. Near the shore of this subtropical sea tuffaceous deposits indicate volcanic activity to the eastward. Similar activity is conspicuously represented in some of the tuffs of the John Day Oligocene, which may be in part the correlative of marine Oligocene. The terrestrial deposits of the John Day, according to Merriam, were formed along the flood plains of an old-age stream. These lowlands were the habitat of oreodons, primitive dogs, saber-tooth cats, rhinoceroses, three-toed horses, and numerous other forms well known through the classical studies made upon this fauna.

The marine Oligocene was deformed, to an extent as yet undetermined, before the advance of the less extensive Monterey Sea These waters were still warm, possessing a fauna similar to that of

California, yet apparently deficient in diatamaceous and radiolarian remains which are associated with the petroliferous deposits of that state. Volcanic activity then became the dominant feature of the period. Olivine basalts, issuing from fissures and vents along the axis of the present Cascades and throughout eastern Oregon, formed vast floods of lava, which rose high upon the flanks of the Blue Mountains. These flows were intermittent, as is attested by interbedded lateritic deposits, frequently containing petrified wood. This epoch of volcanic activity came to a close in middle Miocene time. In the John Day region these lavas were flexed, faulted, and partially eroded before the deposition of the middle Miocene Mascall in structural or erosional basins. Along the axis of the present Cascades these flows were thrown into an anteclinorum now exposed within the gorge of the Columbia. This epoch of deformation was of more than state-wide significance, being recognized in Washington and California.

The upper Miocene record of Oregon west of the Cascades is read mainly in the details of the later history of the then peneplained Klamath region. The marine epoch of Empire time is now thought to be early Pliocene. The upper Miocene floras of adjoining states and that of the eastern Oregon Mascall indicate a moist, warm, temperate climate, in which the camel, the horse, the ancient bear, and the proboscidians thrived. By the close of the Miocene, movements again interrupted the sedimentation in the John Day region, which deformed the Mascall beds. Upon their eroded edges were deposited gravels, tuffs, and flows of the early Pliocene.

Other local lake and flood plain deposits of later Pliocene age occur nearer the Idaho line, giving evidence of the formation of structural basins or changes in drainage as yet but imperfectly deciphered. A depression of a narrow strip paralleling the present shore line developed along the coast in early Pliocene and received the marine sediments of the Empire. The fauna of this sea indicates a cooler climate. This marine epoch was brought to a close by the epeirogenic movements which elevated the entire coast, producing the gentle folds now found in the Empire, probably the faulting and warping of the Klamath peneplain, and perhaps the

formation of the block mountains of eastern Oregon. Erosion soon cut these soft Empire sediments nearly to a base level, producing a second peneplain passing eastward over the Coast Range Differential uplift within the Klamath and Coast Range regions again rejuvenated the streams, which intrenched themselves, maintaining in some instances their old, meandering courses. In late Pliocene or early Pleistocene these same streams cut deep valleys in the then exposed continental shelf, as is now revealed by soundings. The ancient Willamette River may then have carved in part its wide valley, since deeply filled by alluvium. In the meantime the Cascades had been reduced to a region of low relief covered, near the Columbia at least, by gravels of supposed Satsop age.

Following the deposition of these gravels came the final uplift of the Coast Range of Oregon and the extrusion of andesites and rhyolites forming the superstructure of the Cascade Range and the later development of the volcanic cones now dominating the crest line. Climatic changes that had been presaged by the cooler Pliocene climate culminated in the formation of glaciers on the higher peaks of the Cascades, Stein, Blue, and Wallowa mountains. These glaciers soon extended far down their valleys. The cooler and moister climate permitted the development of extensive lakes within the now semiarid region of eastern Oregon.

The life of the earliest Pleistocene is best interpreted from the rich avifauna of Fossil Lake and the marine fauna from a few very local embayments bordering the coast.

The disappearance of most of the Pleistocene glaciers, the deepening of river canyons, the development of alluvial deposits, including auriferous gravels, and the continued volcanic activity include the salient features of late Pleistocene and Recent time.

## IGNEOUS ROCKS

Igneous rocks are found conspicuously developed in three regions in Oregon: (*a*) the Blue Mountains, (*b*) the Cascades, and (*c*) the Klamath Mountains. In the Blue Mountains the dominant type is granodiorite, in the Cascades basalt and andesite, and in the Klamath serpentinized peridotite, gabbro, and granodiorite.

Table I, compiled by Mr. Fred Melzer, a Senior in the department of Geology at Oregon in 1917, gives at a glance most of the general information about our igneous rocks, such as types, localities, frequency of mention in the literature, and the literature citation. From a study of the literature we find that, judging from the number of times mentioned in the literature, the various types of basalt come first, andesites next, followed by metagabbro third, and then comes rhyolite with diabase and diorite a little farther in the rear.

The dominant rock in the Cascade region is the Columbia lava, which is basaltic. The principal rock in the Cascade superstructure is andesite. In the metalliferous districts of the southwest and northeast granodiorite is the chief rock. For a petrographic description of this and the following rocks the reader is referred to Table I.

The serpentinized peridotites in the vicinity of Port Orford are both interesting and valuable economically because of the association of chromite and nickel. According to Diller they were probably intruded in Cretaceous times.

It will be seen from the testimony of the literature that the dominant igneous activity in the state has occurred later in geologic time, in the Mesozoic and Cenozoic. Very little is definitely known of the igneous rocks of the Paleozoic, and little or nothing of the pre-Cambrian, if indeed there were any at all at that time in this state.

Chemically the rocks are alkali-calcic. According to Iddings,[1] "the 76 igneous rocks of the Cascade Mountains that have been analyzed belong in 24 magmatic divisions of the Quantitative system, 56 falling in 5 divisions: tonolose 22, lassenose 11, andose 9, hessose 8, and yellowstones 6, all of which are dosodic. Only 9 of the 76 analyzed are sodipotassic."

Steinmann[2] asserts that the average igneous rock of the South American Cordillera is similar to that of the Pacific Coast of North America. He says that the lavas of the former region are andesites, dacites, and rhyolites, and that granodiorites are the pre-

[1] J. P. Iddings, *Igneous Rocks*, II, 446.

[2] G. Steinmann, *Geolo. Rundschau*, I (1910), 13.

TABLE I

IGNEOUS ROCKS OF OREGON

| Name | Age | Mineral Composition | Texture | Authority | Localities |
|---|---|---|---|---|---|
| | | | | | |
| | | | I. PLUTONIC ROCKS | | |
| Granites: Hornblende biotite granite | Post-Triassic | Like hornblende-biotite granite-augite altering to hornblende | ........ | Grant and Cady* | Haines, Baker Co. |
| Soda granite | Post-Triassic | Quartz, albite, small amount of ferromagnesian minerals, mostly chlorite | Granular | Lindgren | Sparta, Baker Co. |
| Granite from White Point | ........ | Abundant orthoclase, some plagioclase, quartz, biotite, muscovite, and accessories | ........ | A. N. Winchell | White Point, Jackson Co. |
| Granodiorite | Late Mesozoic | Abundant sodic plagioclase = (andesine-oligoclase), subordinate orthoclase and microcline, some quartz; biotite, green hornblende, titanite, pyrite, magnetite, apatite, and zircon | Medium-grained, hypidiomorphic, granular | Lindgren<br>Pardee*<br>Swartley*<br>Calkins, p. 11 S.<br>A. N. Winchell<br>Diller | Bald Mt. batholith, Baker<br>Wallowa Mts.<br>John Day Basin, Middle F<br>Josephine and Jackson Cos. |
| Tonalite | ........ | Sodic plagioclase, quartz, hornblende or biotite, or both, and accessories | ........ | A. N. Winchell | Josephine and Jackson Cos. |
| Diorite | ........ | Sodic plagioclase, hornblende or biotite, or both, accessories | Dark gray granular rock | Lindgren<br>A. N. Winchell<br>Pardee and Hewitt* | Baker Co.<br>Josephine and Jackson Cos. |
| Diorite porphyry | ........ | Larger crystals of plagioclase feldspar, augite, hypersthene, in finer matrix of same minerals plus possibly some quartz | Holocrystalline | Ira A. Williams | Shellrock and Wind Mts.<br>Columbia River |
| Metagabbro | Pre-Tertiary | Calcic plagioclase; abundant augite, mostly altered to hornblende or chlorite; or also secondary quartz, muscovite, epidote, and kaolin | Granitic texture, at times ophitic | Lindgren<br>Pardee and Hewitt<br>A. N. Winchell<br>Diller | Blue Mts.<br>Josephine and Jackson Cos.<br>Port Orford Quadrangle<br>Roseburg Quadrangle |
| Norite | ........ | Plagioclase and inclosed hypersthene; intergrown with pyrrhotite, chalcopyrite, etc. | ........ | A. N. Winchell | Chisholm's copper mine on Evans Creek, Jackson Co |
| Peridotite | Paleozoic (Pardee) | Olivine; pyroxene, amphibole, or both | Coarsely crystalline, heavy, dark rock | A. N. Winchell<br>Pardee and Hewitt* | Riddle, Douglas Co.<br>Along McCully's Fork, Sum |
| Dunite | ........ | Olivine; little pyroxene or amphibole | Olivine, often altering to serpentine | A. N. Winchell | Spanish Gulch and Beach John Day Valley.<br>Waldo Mine at Takilma, phine Co. |
| Pyroxenite | Pre-Eocene (Calkins) | Pyroxene | Coarsely crystalline | Calkins, p. 118<br>A. N. Winchell | Red Mt. |
| Diabase | Eocene (Diller) | Augite, generally uralitized; lime-soda feldspar; sometimes olivine | Fine-grained, dense rock, ophitic structure | Diller<br>Lindgren | Roseburg Quadrangle<br>Blue Mts. |
| | | | II. HYPERBYSSAL (DIKE) ROCKS | | |
| Granite porphyry | Pre-Eocene | Phenocrysts: orthoclase; quartz; plagioclase; in groundmass biotite, apatite, magnetite and zircon | Porphyritic, holocrystalline groundmass | Calkins, p. 117 | Spanish Gulch, Wheeler Co |
| Syenite porphyry | ........ | Orthoclase and hornblende | Porphyritic | Butler and Mitchell | Curry Co., Mt. Emily |
| Granodiorite porphyry | ........ | Feldspar and hornblende | Fine groundmass | Swartley | Blue Mts. |
| Aplite | ........ | Abundant microcline or orthoclase, or both, and quartz. Some plagioclase, biotite, and accessories | ........ | A. N. Winchell<br>Pardee<br>Swartley | Josephine and Jackson Cos.<br>Blue Mts. |
| Tonalite-aplite | ........ | Plagioclase and quartz, little biotite or hornblende | ........ | A. N. Winchell | Grant's Pass, Josephine Co |
| Pegmatite | ........ | Quartz and microcline, coarse muscovite, little plagioclase | Coarse texture | A. N. Winchell<br>Pardee<br>Lindgren | Evans Creek, Jackson Co.<br>Blue Mts. |
| Dacite prophyry | ........ | Phenocrysts: feldspar (labradorite), less prominently quartz, some hornblende or chlorite | Porphyritic; crystalline groundmass of quartz and feldspar | Diller | Port Orford Quadrangle<br>Bohemia mining region<br>Grant's Pass, Josephine Co. |
| Malchite | ........ | Abundant sodic plagioclase, hornblende, sometimes quartz | Aplitic texture | A. N. Winchell | Ashland mine and other loca in Josephine and Jackson |
| Kersantite | ........ | Biotite and plagioclase | ........ | A. N. Winchell<br>Lindgren | Josephine and Jackson Cos.<br>Blue Mts. |
| Spessartite | ........ | Abundant hornblende and some plagioclase | ........ | A. N. Winchell | Near Jacksonville |
| | | | III. VOLCANIC ROCKS | | |

TABLE I

IGNEOUS ROCKS OF OREGON

| Mineral Composition | Texture | Authority | Localities | Remarks |
|---|---|---|---|---|
| **I. PLUTONIC ROCKS** | | | | |
| Like hornblende-biotite granite-augite altering to hornblende | ........................ | Grant and Cady* | Haines, Baker Co. | |
| Quartz, albite, small amount of ferro-magnesian minerals, mostly chlorite | Granular | Lindgren | Sparta, Baker Co. | |
| bundant orthoclase, some plagioclase, quartz, biotite, muscovite, and accessories | ........................ | A. N. Winchell | White Point, Jackson Co. | |
| bundant sodic plagioclase = (andesine-oligoclase), subordinate orthoclase and microcline, some quartz; biotite, green hornblende, titanite, pyrite, magnetite, apatite, and zircon | Medium-grained, hypidiomorphic, granular | Lindgren<br>Pardee*<br>Swartley*<br>Calkins, p. 11 S.<br>A. N. Winchell<br>Diller | Bald Mt. batholith, Baker Co.<br>Wallowa Mts.<br>John Day Basin, Middle Fork<br>Josephine and Jackson Cos. | It is with this rock, especially in the Blue Mts., that the gold-bearing quartz veins are associated. |
| odic plagioclase, quartz, hornblende or biotite, or both, and accessories | ........................ | A. N. Winchell | Josephine and Jackson Cos. | |
| odic plagioclase, hornblende or biotite, or both, accessories | Dark gray granular rock | Lindgren<br>A. N. Winchell<br>Pardee and Hewitt* | Baker Co.<br>Josephine and Jackson Cos. | Occurs as marginal variation of granodiorite and tonalite batholiths in both localities. |
| arger crystals of plagioclase feldspar, augite, hypersthene, in finer matrix of same minerals plus possibly some quartz | Holocrystalline | Ira A. Williams | Shellrock and Wind Mts.<br>Columbia River | This rock is of the plutonic type, since it occurs as an intruded batholith, in spite of the name "porphyry." It is possible that further work may identify it with one of the other types described. |
| alcic plagioclase; abundant augite, mostly altered to hornblende or chlorite; or also secondary quartz, muscovite, epidote, and kaolin | Granitic texture, at times ophitic | Lindgren<br>Pardee and Hewitt<br>A. N. Winchell<br>Diller | Blue Mts.<br>Josephine and Jackson Cos.<br>Port Orford Quadrangle<br>Roseburg Quadrangle | These rocks are alteration products of fresh gabbro, which itself is nowhere prominent.<br>Winchell employs the term. Saussurite (=Metagabbro). |
| lagioclase and inclosed hypersthene; intergrown with pyrrhotite, chalcopyrite, etc. | ........................ | A. N. Winchell | Chisholm's copper mine on Evans Creek, Jackson Co. | |
| livine; pyroxene, amphibole, or both | Coarsely crystalline, heavy, dark rock | A. N. Winchell<br>Pardee and Hewitt* | Riddle, Douglas Co.<br>Along McCully's Fork, Sumpter | |
| livine; little pyroxene or amphibole | Olivine, often altering to serpentine | A. N. Winchell | Spanish Gulch and Beach Cr. John Day Valley.<br>Waldo Mine at Takilma, Josephine Co. | Winchell mentions Dunite as a variation of peridotite, in the case where olivine becomes the dominant constituent. |
| yroxene | Coarsely crystalline | Calkins, p. 118<br>A. N. Winchell | Red Mt. | The two varieties described differ considerably. |
| ugite, generally uralitized; lime-soda feldspar; sometimes olivine | Fine-grained, dense rock, ophitic structure | Diller<br>Lindgren | Roseburg Quadrangle<br>Blue Mts. | |
| **II. HYPERBYSSAL (DIKE) ROCKS** | | | | |
| henocrysts: orthoclase; quartz; plagioclase; in groundmass biotite, apatite, magnetite and zircon | Porphyritic, holocrystalline groundmass | Calkins, p. 117 | Spanish Gulch, Wheeler Co. | |
| rthoclase and hornblende | Porphyritic | Butler and Mitchell | Curry Co., Mt. Emily | The descriptions given for these two types are not sufficiently detailed to enable placing them accurately. |
| eldspar and hornblende | Fine groundmass | Swartley | Blue Mts. | |
| bundant microcline or orthoclase, or both, and quartz. Some plagioclase, biotite, and accessories | ........................ | A. N. Winchell<br>Pardee<br>Swartley | Josephine and Jackson Cos.<br>Blue Mts. | |
| lagioclase and quartz, little biotite or hornblende | ........................ | A. N. Winchell | Grant's Pass, Josephine Co. | |
| uartz and microcline, coarse muscovite, little plagioclase | Coarse texture | A. N. Winchell<br>Pardee<br>Lindgren | Evans Creek, Jackson Co.<br>Blue Mts. | Lindgren describes a rare pegmatite from the Coyote Hills, Baker County. |
| henocrysts: feldspar (labradorite), less prominently quartz, some hornblende or chlorite | Porphyritic; crystalline groundmass of quartz and feldspar | Diller | Port Orford Quadrangle<br>Bohemia mining region<br>Grant's Pass, Josephine Co. | |
| bundant sodic plagioclase, hornblende, sometimes quartz | Aplitic texture | A. N. Winchell | Ashland mine and other localities in Josephine and Jackson Cos. | Winchell's malchite is very closely related to Diller's dacite porphyry, the main difference being texture. |
| iotite and plagioclase | ........................ | A. N. Winchell<br>Lindgren | Josephine and Jackson Cos.<br>Blue Mts. | |
| bundant hornblende and some plagioclase | ........................ | A. N. Winchell | Near Jacksonville | |

III. VOLCANIC ROCKS

| | | | | | |
|---|---|---|---|---|---|
| Syenite porphyry..... | ............... | Orthoclase and hornblende | Porphyritic | Butler and Mitchell | Curry Co., Mt. Emily |
| Granodiorite porphyry. | ............... | Feldspar and hornblende | Fine groundmass | Swartley | Blue Mts. |
| Aplite.............. | ............... | Abundant microcline or orthoclase, or both, and quartz. Some plagioclase, biotite, and accessories | ........................ | A. N. Winchell<br>Pardee<br>Swartley | Josephine and Jackson Cos.<br>Blue Mts. |
| Tonalite-aplite........ | ............... | Plagioclase and quartz, little biotite or hornblende | ........................ | A. N. Winchell | Grant's Pass, Josephine Co |
| Pegmatite........... | ............... | Quartz and microcline, coarse muscovite, little plagioclase | Coarse texture | A. N. Winchell<br>Pardee<br>Lindgren | Evans Creek, Jackson Co.<br>Blue Mts. |
| Dacite prophyry...... | ............... | Phenocrysts: feldspar (labradorite), less prominently quartz, some hornblende or chlorite | Porphyritic; crystalline groundmass of quartz and feldspar | Diller | Port Orford Quadrangle<br>Bohemia mining region<br>Grant's Pass, Josephine Co. |
| Malchite............ | ............... | Abundant sodic plagioclase, hornblende, sometimes quartz | Aplitic texture | A. N. Winchell | Ashland mine and other loca in Josephine and Jackson |
| Kersantite........... | ............... | Biotite and plagioclase | ........................ | A. N. Winchell<br>Lindgren | Josephine and Jackson Cos.<br>Blue Mts. |
| Spessartite.......... | ............... | Abundant hornblende and some plagioclase | ........................ | A. N. Winchell | Near Jacksonville |
| | | | III. VOLCANIC ROCKS | | |
| Rhyolite............ | Eocene or later (Calkins) | Phenocrysts: quartz, alkali feldspar (orthoclase or sanidine), oligoclase, accessories | Light-colored rocks, glassy groundmass, often devitrified in whole or part | Calkins, pp. 141 and 152<br>Diller<br>Lindgren<br>Pardee<br>Winchell | Clarno's Ferry } John Day<br>Antelope Valley } region<br>Roseburg Quadrangle<br>Blue River mining district<br>Blue Mts.<br>Josephine and Jackson Cos. |
| Spherulitic type..... | Eocene | Phenocrysts: quartz, sanidine, and acid plagioclase, all sparingly present | Lithoidal groundmass containing large and small spherulites | Calkins, p. 138 | Current Creek Hill, John region |
| Obsidian.......... | ............... | ................................ | Glassy acid rock | Russel | S.E. Oregon |
| Rhyodacite.......... | ............... | Phenocrysts: plagioclase and orthoclase in a fine quartz matrix | ........................ | A. N. Winchell | Galice district, Josephine ( |
| Dacite............... | ............... | Phenocrysts: plagioclase and quartz; groundmass of plagioclase, quartz, etc. | Groundmass, hypocrystalline | A. N. Winchell<br>Lindgren | Galice district, Josephine (<br>Hereford, Baker Co. |
| Hypersthene dacite.... | ............... | Phenocrysts: labradorite, hypersthene, brown hornblende; sometimes augite and olivine. Groundmass varies in different types | Porphyritic, groundmass varies from glassy to crystalline | Patton, pp. 3, 99–141 | Crater Lake |
| Andesites:<br>Hornblende andesite. | Eocene or later (Calkins) | Phenocrysts: labradorite and more acid feldspar, brown pleochroic hornblende, accessory apatite and magnetite. Groundmass, andesine feldspar, etc. | Porphyritic, groundmass minutely crystalline | Calkins, pp. 128–29<br>Lindgren<br>Diller | Hald's Canon<br>Burnt River and Middle I John Day<br>Bonneville and Cascades |
| Hornblende hypersthene andesite... | Clarno and later (Calkins) | Phenocrysts: basic labradorite, iddingsite pseudomorphs after hypersthene, hornblende, zeolites | Porphyritic, groundmass, hyalopilitic | Calkins, p. 129<br>Diller | Clarno's Ferry<br>Bonneville<br>Mt. Hood, Cascades |
| Hypersthene andesite | Pleistocene<br>Clarno (Calkins) | Phenocrysts: basic plagioclase, hypersthene, augite, magnetite, seldom olivine and hornblende | Groundmass distinguishes two types (Patton):<br>A. Hyalopilitic<br>B. Hypocrystalline<br>1. Docitic<br>2. Holocrystalline | Patton, pp. 69–99<br>Calkins, pp. 122–28<br>Lindgren, p. 592 | Crater Lake<br>Hald's Canon<br>Susanville to Prairie<br>Cascades |
| Augite andesite..... | ............... | Phenocrysts: plagioclase, augite, at times hypersthene, but subordinate to augite | Minutely porphyritic, groundmass somewhat ophitic | Diller | Roseburg Quadrangle<br>Grant's Pass Quadrangle<br>Bohemia mining district |
| Basalts:<br>Olivine basalt ...... | Miocene | Basic plagioclase (labradorite); common pale brown augite, subordinate olivine, iron ore; apatite, secondary iddingsite and zeolites | Groundmass intersertal to ophitic holocrystalline | Calkins, pp. 159–65<br>Diller<br>Lindgren<br>A. N. Winchell | Eastern Oregon<br>Coos Bay and Roseburg ( rangles<br>Josephine and Jackson Cos |
| Olivine-free basalt... | Mascall (Calkins) | Basic plagioclase, augite, abundant accessory magnetite | Groundmass is typically intersertal | Calkins, pp. 165–66<br>Lindgren | John Day basin |
| Quartz-bearing hypersthene basalt.. | Eocene (Calkins) | Phenocrysts: pleochroic hypersthene and green augite, olivine, quartz showing magmatic corrosion. Microlites of labradorite | Feltwork groundmass of pyroxene, feldspar, and brown glass | Calkins, pp. 134–46 | Cherry Creek, John Day b |
| Hypersthenebasalt.. | Post-Tertiary | Very basic plagioclase, augite, hypersthene olivine, magnetite | Structure, interstitial to porphyritic | Patton, pp. 141–63 | Crater Lake |
| Andesitic basalt... | ............... | A type approaching in composition and structure Patton's hypersthene andesite above | ........................ | Patton | Crater Lake |
| Augitite............ | ............... | Pyroxene | ........................ | A. N. Winchell | Takilma, Josephine Co. |

* M. R. of O. = Mineral Resources of Oregon.

| | | | | |
|---|---|---|---|---|
| Orthoclase and hornblende | Porphyritic | Butler and Mitchell | Curry Co., Mt. Emily | The descriptions given for these two types are not sufficiently detailed to enable placing them accurately. |
| Feldspar and hornblende | Fine groundmass | Swartley | Blue Mts. | |
| Abundant microcline or orthoclase, or both, and quartz. Some plagioclase, biotite, and accessories | ........................ | A. N. Winchell<br>Pardee<br>Swartley | Josephine and Jackson Cos.<br>Blue Mts. | |
| Plagioclase and quartz, little biotite or hornblende | ........................ | A. N. Winchell | Grant's Pass, Josephine Co. | |
| Quartz and microcline, coarse muscovite, little plagioclase | Coarse texture | A. N. Winchell<br>Pardee<br>Lindgren | Evans Creek, Jackson Co.<br>Blue Mts. | Lindgren describes a rare pegmatite from the Coyote Hills, Baker County. |
| Phenocrysts: feldspar (labradorite), less prominently quartz, some hornblende or chlorite | Porphyritic; crystalline groundmass of quartz and feldspar | Diller | Port Orford Quadrangle<br>Bohemia mining region<br>Grant's Pass, Josephine Co. | |
| Abundant sodic plagioclase, hornblende, sometimes quartz | Aplitic texture | A. N. Winchell | Ashland mine and other localities in Josephine and Jackson Cos. | Winchell's malchite is very closely related to Diller's dacite porphyry, the main difference being texture. |
| Biotite and plagioclase | ........................ | A. N. Winchell<br>Lindgren | Josephine and Jackson Cos.<br>Blue Mts. | |
| Abundant hornblende and some plagioclase | ........................ | A. N. Winchell | Near Jacksonville | |

III. VOLCANIC ROCKS

| | | | | |
|---|---|---|---|---|
| Phenocrysts: quartz, alkali feldspar (orthoclase or sanidine), oligoclase, accessories | Light-colored rocks, glassy groundmass, often devitrified in whole or part | Calkins, pp. 141 and 152<br>Diller<br>Lindgren<br>Pardee<br>Winchell | Clarno's Ferry } John Day<br>Antelope Valley } region<br>Roseburg Quadrangle<br>Blue River mining district<br>Blue Mts.<br>Josephine and Jackson Cos. | Calkins and Lindgren describe types with microcrystalline and cryptocrystalline groundmass. Calkins also described a fibrous groundmass. Sometimes the groundmass shows considerable alteration |
| Phenocrysts: quartz, sanidine, and acid plagioclase, all sparingly present | Lithoidal groundmass containing large and small spherulites | Calkins, p. 138 | Current Creek Hill, John Day region | |
| .............................. | Glassy acid rock | Russel | S.E. Oregon | |
| Phenocrysts: plagioclase and orthoclase in a fine quartz matrix | ........................ | A. N. Winchell | Galice district, Josephine Co. | |
| Phenocrysts: plagioclase and quartz; groundmass of plagioclase, quartz, etc. | Groundmass, hypocrystalline | A. N. Winchell<br>Lindgren | Galice district, Josephine Co.<br>Hereford, Baker Co. | |
| Phenocrysts: labradorite, hypersthene, brown hornblende; sometimes augite and olivine. Groundmass varies in different types | Porphyritic, groundmass varies from glassy to crystalline | Patton, pp. 3, 99–141 | Crater Lake | Dacites are the latest flows seen on rim of Crater Lake. |
| Phenocrysts: labradorite and more acid feldspar, brown pleochroic hornblende, accessory apatite and magnetite. Groundmass, andesine feldspar, etc. | Porphyritic, groundmass minutely crystalline | Calkins, pp. 128–29<br>Lindgren<br>Diller | Hald's Canon<br>Burnt River and Middle Fork, John Day<br>Bonneville and Cascades | |
| Phenocrysts: basic labradorite, iddingsite pseudomorphs after hypersthene, hornblende, zeolites | Porphyritic, groundmass, hyalopilitic | Calkins, p. 129<br>Diller | Clarno's Ferry<br>Bonneville<br>Mt. Hood, Cascades | Feldspars in part altered to stilbite and heulandite which Calkins calls characteristic of Clarno andesites. |
| Phenocrysts: basic plagioclase, hypersthene, augite, magnetite, seldom olivine and hornblende | Groundmass distinguishes two types (Patton):<br>A. Hyalopilitic<br>B. Hypocrystalline<br>1. Docitic<br>2. Holocrystalline | Patton, pp. 69–99<br>Calkins, pp. 122–28<br>Lindgren, p. 592 | Crater Lake<br>Hald's Canon<br>Susanville to Prairie<br>Cascades | The andesites are the oldest of Crate-Lake effusives. Calkins' hypers sthene shows alteration to iddingrite. |
| Phenocrysts: plagioclase, augite, at times hypersthene, but subordinate to augite | Minutely porphyritic, groundmass somewhat ophitic | Diller | Roseburg Quadrangle<br>Grant's Pass Quadrangle<br>Bohemia mining district | Although no such full descriptions are given for this rock as for the foregoing, the evident subordinate character of the hypersthene makes possible distinction. |
| Basic plagioclase (labradorite); common pale brown augite, subordinate olivine, iron ore; apatite, secondary iddingsite and zeolites | Groundmass intersertal to ophitic holocrystalline | Calkins, pp. 159–65<br>Diller<br>Lindgren<br>A. N. Winchell | Eastern Oregon<br>Coos Bay and Roseburg Quadrangles<br>Josephine and Jackson Cos. | This includes the widespread "Columbia River Lavas." |
| Basic plagioclase, augite, abundant accessory magnetite | Groundmass is typically intersertal | Calkins, pp. 165–66<br>Lindgren | John Day basin | This includes Winchell's auganite. |
| Phenocrysts: pleochroic hypersthene and green augite, olivine, quartz showing magmatic corrosion. Microlites of labradorite | Feltwork groundmass of pyroxene, feldspar, and brown glass | Calkins, pp. 134–46 | Cherry Creek, John Day basin | |
| Very basic plagioclase, augite, hypersthene olivine, magnetite | Structure, interstitial to porphyritic | Patton, pp. 141–63 | Crater Lake | Occurs only as flows from cones on outer slope of Mt. Mazama. Russel's Pleistocene basalt of southeastern Oregon may belong here. |
| A type approaching in composition and structure Patton's hypersthene andesite above | ........................ | Patton | Crater Lake | |
| Pyroxene | ........................ | A. N. Winchell | Takilma, Josephine Co. | |

of Oregon.

vailing intrusives. In this connection Becker and W. D. Smith have repeatedly called attention to the relation between the igneous rocks of the Philippines and of Oregon. If we pass a great circle along the axis of the Cascades we shall find that it will pass remarkably close to the Cordilleras of Japan and the Philippines, and it is only to be expected that we would find this petrographic similarity along such a great and persistent tectonic line.

Definite figures as to the size of the intrusive batholiths in Oregon are at present unavailable. In the Blue Mountains the granodiorite is very prominent and attains elevations close to 10,000 feet and covers hundreds of square miles, while in the Cascade region it is seen in one or two localities only, and these low down and in very limited exposures. In the Siskiyou region (southwest) also there are large masses of granodiorite.

## ECONOMIC GEOLOGY

In 1867 the mineral production of Oregon, according to government estimates at that time, was about twenty million dollars and was practically, if not entirely, from gold placers.

In 1917 the value of the mineral products of the state which were mined amounted to about $3,500,000. The year 1918 saw slightly less, owing to war conditions. A few years ago the production was almost nil, so that we are now on the upgrade again, and a substantial gold-mining industry largely from quartz lodes is being established.

On the mineral map (Fig. 3) are shown the principal mineral localities in the state. It will be seen from a glance that the two metalliferous districts are in the southwest and in the northeast, the Siskiyou and Blue Mountains respectively. Baker County produces the larger part of the gold of Oregon, and the Cornucopia district is the leading district of that county.

While there are many copper prospects, the most noteworthy are those near Homestead on the Snake River, and those near Waldo, twenty miles southwest of Grant's Pass, in the southwestern part of the state.

During the war there was a rather notable development of the chromite industry in these two regions, and one manganese locality

(Lake Creek) was being vigorously prospected, with the hope of a substantial production very soon.

Some platinum is recovered with gold in the beach placers to the north and south of Marshfield, but the yield has not yet had any appreciable effect on the industry.

Nickel deposits occur near Riddles, Douglas County, but no production is reported at the present time.

One quicksilver mine is located near Cottage Grove, Lane County, which, however, has not had a very prosperous history.

Common brick and drain tile are made at many localities in Oregon, but clays suitable for pottery of the better grades have either not been located, or if known, have not been worked.

All attempts to find oil in commercial quantities in Oregon have so far failed. At the present time drilling is being done near Waldport on the coast, and near Roseburg and Vale on the eastern boundary of the state. So far no success has been met in these undertakings. Near McMinnville, Yamhill County, there are several salt springs and gas wells, one of which in Polk County illuminates a ranch house and is used for cooking. This well has given off natural gas for over thirty years. No scientific development of this field has yet been undertaken. It seems to be the most promising place in Oregon for natural gas, and possibly petroleum. Some "shows" of oil have just recently been reported from a Harney County (southeastern Oregon) well, now down to 1,241 feet.

A fair grade of sub-bituminous coal of Tertiary age is mined in the small basins of marine Tertiaries near the coast. The production is small and comes from two or three small mines. The daily output probably has never exceeded fifty tons.

A great deal of crushed stone, mainly basalt and diabase, is utilized annually on our highways. Limestone is found in both the northeast and southwest portions of the state. The product is distributed largely by the State Lime Board.

The most valuable and unique decorative stone, a handsome black marble, anywhere in the state and perhaps anywhere in the Pacific Northwest is quarried near Enterprise, Wallowa County.

The state of Oregon cannot be said to be a mining state, though it has a promising future in this direction. The state is very

wisely doing something to aid this important industry in supporting a State Bureau of Mines; an appropriation of $50,000 for the biennium has just been granted it.

MINERAL PRODUCTION IN OREGON*

FOR 1917

| | |
|---|---|
| Gold | $1,491,798.00 |
| Platinum | 65 ounces |
| Silver | 125,656 fine ounces |
| Copper | 2,474,487 pounds |
| Chromite | 6,700 tons |
| Lead | 28,000 pounds |

NON-METALS, 1916

| | |
|---|---|
| Coal | 42,592 tons |
| Mineral water | 30,920 gallons |
| Building sand and gravel | 161,761 tons |
| Crushed stone (1917) | 282,732 tons |

*By courtesy of Charles G. Yale, statistician, United States Geological Survey.

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